Ministry of Shipping,
Road Transport
& Highways

POCKET BOOK FOR BRIDGE ENGINEERS

(First Revision)

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Ministry of Shipping, Road Transport & Highways

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FOREWORD

The first edition of this Pocket Book was published in December 1984. It was primarily intended for use as a ready reference for the bridge engineers including those at the grass root level of management both in highway administration and construction industry. The publication at that time fulfilled the long felt need of the bridge engineering profession in this country.

The pocket book has proved very popular with bridge engineers and has generated awareness among the engineers at the grass root level. The present edition of this pocket book is being brought out after revision taking into account the feedback received from the field engineers, the changes in administrative and technical policies and procedure by the Ministry of Surface Transport and includes new chapters on topics of Quality Systems, Procedure for approval for projects under BOT Scheme, Repair and Rehabilitation Techniques for Bridges, etc. A modified method for assessment of design discharge using unit hydrograph method has also been included. The pocket book is divided into 14 sections and gives information and guidelines on all aspect of bridge engineering, such as, preliminary project preparation, detailed project preparation, procedure for inviting tenders and approval, construction procedure and maintenance mostly drawn from the existing publications of IRC and the Ministry's circulars. Because of the limitation of size, the pocket book cannot be expected to cover all the details and, as such, should not be considered as a substitute for the standard specifications, code of practice, etc. However, for convenience of reference, a classified list of IRC publications has been appended at the end. This pocket book has been revised by four experts namely, Shri D.K. Rastogi, Retd. CE, MORT&H, Shri O.N. Saxena, Retd. C.E., MORT&H, Shri R.S. Ninan and Shri A.N. Dhodapkar, Superintending Engineers of MORT&H. The pocket book was got revised by a committee comprising of 3 Chief Engineers, namely, Shri V. Velayutham, CE(B)S&R, Shri G. Sharan, CE(P-2), Shri Krishan Kant, CE. Shri Nirmal Jit Singh and Shri A.V. Sinha, Chief Engineers, Shri Manoj Kumar, SE(PIC) in MORT&H have also made valuable contribution towards improvement in the contents of the pocket book. Shri I.K. Pandey, SE(B)S&R as Member-Secretary of CE's committee coordinated the above work and carried out modifications in the

pocket book to bring it in tune with latest technical circulars issued by the Ministry and IRC Codes. He also drafted the newly added chapters of the pocket book. I take this opportunity to acknowledge the services rendered by all these experts. I am also grateful to my Technical Secretary, Shri B.N. Singh, for going through the entire material and making certain important suggestions which have helped in the finalisation of this document. I would also like to appreciate the efforts of Miss Richa Nigam, Assistant Executive Engineer, MORT&H and Shri Rajender Kumar, Assistant Engineer, MORT&H for compilation of this pocket book.

I would also like to acknowledge the services of Mrs. Rajeshwari Shankar, PA, MORT&H and Shri Shashi Kumar, Ferro-Printer, MORT&H, for their dedicated assistance.

I hope this present revised edition of the pocket book will prove to be as popular as the earlier edition and continue to be useful for day-to-day reference for all the bridge engineers. The compilation of this kind of pocket book will need updating from time-to-time. In this context, I would welcome suggestions and feed back from the profession so that we can improve and update the pocket book in the years to come.

(PRAFULLA KUMAR)
Director General
(Road Development) &
Additional Secretary
to the Govt. of India.

New Delhi
November, 2000.

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1. INTRODUCTION

1. INTRODUCTION

A bridge project from its conception to completion involves various stages of planning, design, approval/sanction, tendering and execution. Also, inspections, maintenance and repairs are continuing activities for enhancing the service life of the structure. This pocket book has been specifically aimed at giving the practising engineers the basic information on these aspects.

A bridge project from conception to construction and final completion of the bridge involves a number of major activities which can be summarised as follows:-

Start - administrative decision for constructing a bridge

Feasibility studies

Preliminary project preparation – site selection. Preliminary survey and investigation including hydraulic survey, subsoil investigation, fixation of span arrangements and selection of type of structure. Preliminary design of various components of bridge, preliminary cost estimates.

Detailed project preparation – detailed survey, hydraulic design, subsurface investigation, detailed structural designs, detailed estimate and detailed project report.

Technical approval and financial sanction –

Decision to take up work from plan funds or to invite private entrepreneurs.

Approval of Tenders and Revised cost if necessary and start of construction work

Construction — project scheduling and monitoring of quality and progress of works

Inspection and maintenance of bridges

Note: Bridges are usually designed for at least 50 years life and should cater to the projected traffic demands. Utmost care should be exercised in site investigations by following the procedures outlined in the subsequent chapters ensuring only preparation of thoroughly investigated projects which will ultimately facilitate speedy construction, help in timely completion, reduced construction and maintenance costs.

2. PROJECT PREPARATION

2. PROJECT PREPARATION

Preparation of a detailed project report is a pre-requisite for proper evaluation of the project, its approval by competent authority and finally its execution. Properly prepared project report is very helpful in ensuring timely completion of project thereby ensuring fullest advantage of the project avoiding time and cost overruns. Project preparation activity can be divided into the following three broad stages:-

(1) Feasibility Study
(2) Preliminary Project Report
(3) Detailed Project Report

For detailed guidelines reference may be made to Special Publication No.54 – "Project Preparation Manual for Bridges" published by Indian Roads Congress.

Empanelment of consultants for highway and bridge works is carried out by the Ministry to short list competent consultants. This is being done in the following categories:

CATEGORY I - HIGHWAY PROJECTS

Category-IA : All types of Highway Projects including four/six laning and expressways but excluding major bridges (total length>60 m), flyovers, grade separators and bridges with innovative design.

Category-IB : Smaller Highway Projects of one/two laning and four laning (upto 20 kms length) but excluding major bridges (total length>60 m), flyovers, grade separators and bridges with innovative design.

CATEGORY II - BRIDGE PROJECTS

Category-IIA : All types of bridges, flyovers and grade separators with immediate approaches but excluding bridges, flyovers and grade separators with individual span > 50 m or bridges with innovative design.

Category - IIB : Bridge Inspection and Rehabilitation

CATEGORY III - SPECIALISED STUDIES IN THE AREA OF TRAFFIC AND TRANSPORTATION ENGINEERING AND HIGHWAY PLANNING

CATEGORY IV - GEO-TECHNICAL INVESTIGATIONS FOR MAJOR BRIDGES, HIGH EMBANKMENTS, FLYOVERS AND GRADE SEPARATORS

2. The work of detailed project preparation for National Highways and centrally sponsored works may be carried out through the empanelled consultants only. The latest list of the empanelled consultants may be obtained from the Ministry.

2.1. **Feasibility Study**

2.1.1. The project preparation for a bridge work starts with the identification of the project. This phase is known as the pre-feasibility stage. For this stage, broad features of the project are identified, the possible locations, nature of crossing, traffic dispersal system for different alternatives are identified. The effect of implementation of the project on the traffic scenario in immediate vicinity is also considered. The reconnaissance visit to the area of the intended site is sufficient at this stage.

2.1.2. In the feasibility stage, preliminary surveys, data collections and investigations are carried out. Alternative sites are investigated, design and rough cost estimates for various alternatives are made. The feasibility report covering the recommended alignment including alternatives considered, span arrangements, preliminary cost estimates, economic and financial viability is prepared. This should include recommendations regarding need for carrying out model studies where required, special design requirements for the projects if any and schedule for all the pre-construction activities. Feasibility study should also cover the following aspects:-

(i) The main purpose of the bridge project i.e. the trunk route, economic or inter state importance, access to ports, tourism, agricultural development etc, the place

of the project in the road development programme and the priority assigned to.

(ii) The geographical features of the area such as size, economic (industrial and agricultural), other traffic generated activities in the area, main population centers, their size projections and growth rates, and Government's economic programme for the development.

(iii) Measurable and non-measurable benefits should be listed. The former may consider reduction in operation costs, reduction in travel time for goods and passengers, reduction in maintenance costs in case a old bridge is replaced. The latter may include social and economic development of the adjacent area consequent to the construction of the bridge.

(iv) The method adopted for economic appraisal, economic analysis of the project, rate of return and viable return period.

(v) A cost benefit analysis should be enclosed and results critically discussed. For calculation of cost benefit analysis, a reference may be made to IRC SP-30:1993, "Manual on Economic Evaluation of Highway Projects in India (First revision)".

2.2. Preliminary Project Preparation

Preliminary project preparation involves various stages like recognition of the need, study of maps, reconnaisance survey leading to selection of alternative sites, preliminary survey and investigation including subsoil investigations and collection of hydraulic data leading to final site selection and all these activities have to be systematically planned and carried out in their logical sequence.

2.2.1. **Bridge sitting and road alignment :** The considerations which decide the inter-se priority between a suitable bridge site and suitable road alignment will be guided by the following principles:-

(i) The location of a bridge upto a length of 60 metres shall

be governed by the suitability of alignment of the road unless there are some special problems at that crossing with regard to design / maintenance of the bridge.

(ii) For bridges having a length between 60 and 300 metres both suitability of the site of the bridge and that of the alignment of the approaches shall be considered together.

(iii) For bridges having total length more than 300 metres, the requirement of a good site for the bridge shall have the precedence and the alignment of the approaches will have to conform to the selected bridge site.

(iv) Where existing two lane highway is proposed to be widened to four-lane width, the location of the additional two-lane bridge shall be governed by factors mentioned in para 2.2.3.1 (ix) below.

2.2.2. **Reconnaissance survey :** In case of an entirely new alignment, the site selection may have to start with the study of available maps before starting the reconnaisance. Usually, topo sheets in the scales 1:2,50,000 and 1:50,000 are available from the Survey of India. In case of bridges upto 300 m length, two or three possible road alignments should be marked on the topo sheets considering the topography of the land, land-use, soil type, water bodies, marshes, control points, river profile, straightness of the reach, width of crossing, presence of high banks etc. The two or three possible alignments may have to be considered for reconnaissance. Some landmarks for easy identification during reconnaissance may also have to be marked on topo sheets.

2.2.3 Factors deciding site selection

2.2.3.1. Adequate efforts made in selection of a good site for locating a bridge will be amply rewarded in the form of reduced cost of the project and trouble free performance of the bridge. The factors that have to be considered in the selection of a site are indicated below. Though it may not be feasible to satisfy all desirable attributes simultaneously, the selected site should represent the most desirable mix of the attributes consistent with overall economy, including the cost of approaches.

(i) **Permanency of the channel:** It has to be ascertained from different maps prepared over a long period of time that the river does not have any tendency to meander at the proposed site.

(ii) **Presence of high and stable banks**: The presence of high inerodible banks generally offers an ideal site, which reduces the cost of approach embankments and their protection works.

(iii) **Narrowness of the channel and large average depth compared to maximum depth:** This ensures large average depth of flow compared to maximum depth of flow and reduced water way which greatly reduces the overall cost of the bridge structure.

(iv) **Straight reach of the river u/s and d/s of the proposed site:** Straightness of the reach both u/s and d/s ensures uniform distribution of discharge/velocity. Curvature in the stream especially on the u/s leads to obliquity and concentration of the flow on the convex side leading to higher scour, and consequent cost of foundation and protection works. If the bank on the convex side is erodible, it may lead to heavy recurring expenditure in protecting the abutment and the embankment on that side.

(v) **Freedom from islands or any form of obstruction both u/s and d/s** : Any shoal formation disturbs flow characteristics. Gradual silting of one or more channels results in increased concentration of flow in other channels leading to higher scour or bank erosion, outflanking of the bridge etc. The site should also be away from confluence of tributaries where turbulance and obliquity of flow can be expected which results in higher unpredictable scour and water current forces on substructure.

(vi) **Possiblity of right angled crossings**: Right angled crossing offers minimum possible bridge length and reduces chances of obliquity of flow with respect to the substructure.

(vii) It is preferable to site the bridge on u/s of the existing causeway, if any.

(viii) **Possibility of good approach alignment**: Curves except gentle ones are preferably to be avoided on approaches and bridge proper from visibility and safety considerations.

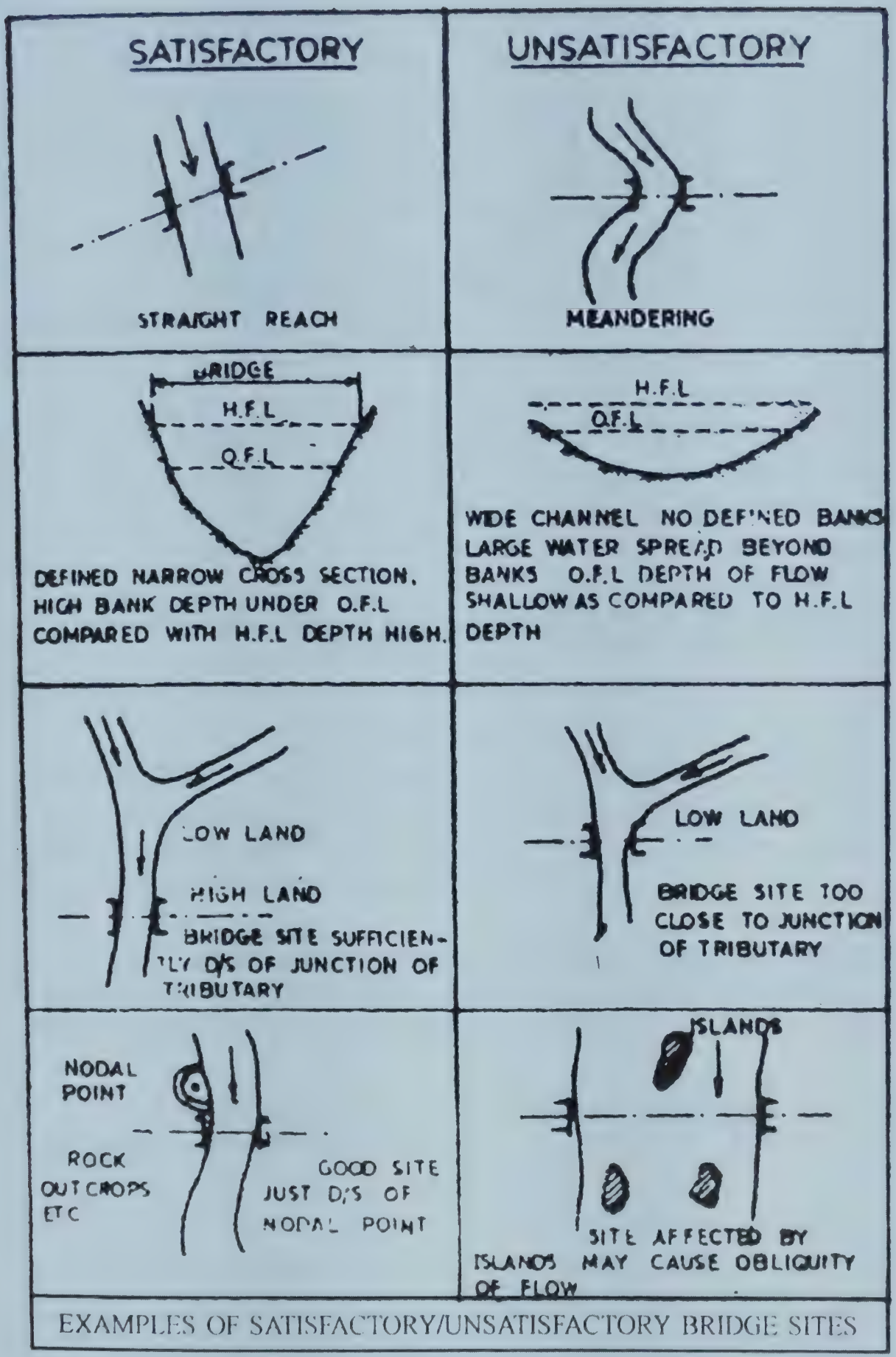
(ix) Where existing two lane highway is proposed to be widened to four-lane width, the additional two-lane bridge shall be sited as close to the existing bridge as possible. However, in case of bridges having well foundations, distance sufficient for generation of passive resistance of soil shall be provided.

Some typical examples of satisfactory and unsatisfactory siting of bridges are indicated in Fig 2.2.1.

2.2.3.2. **Geographical characteristics of the rivers in India**, to the extent affecting siting of bridges can be broadly classified as under:-

(i) **Rivers in Deccan Plateau:** Rivers in this terrain have carved out deep channels in rock with relatively stable banks and sound foundation strata. Selection of sites for bridges in such areas normally does not pose any special problems. The only point needing consideration is the relative economy of a site offering deep and narrow gorge as against one which is shallow and wide. However, the most suited selection will be the one in which the total cost of bridge and approaches is minimum and has lesser maintenance costs.

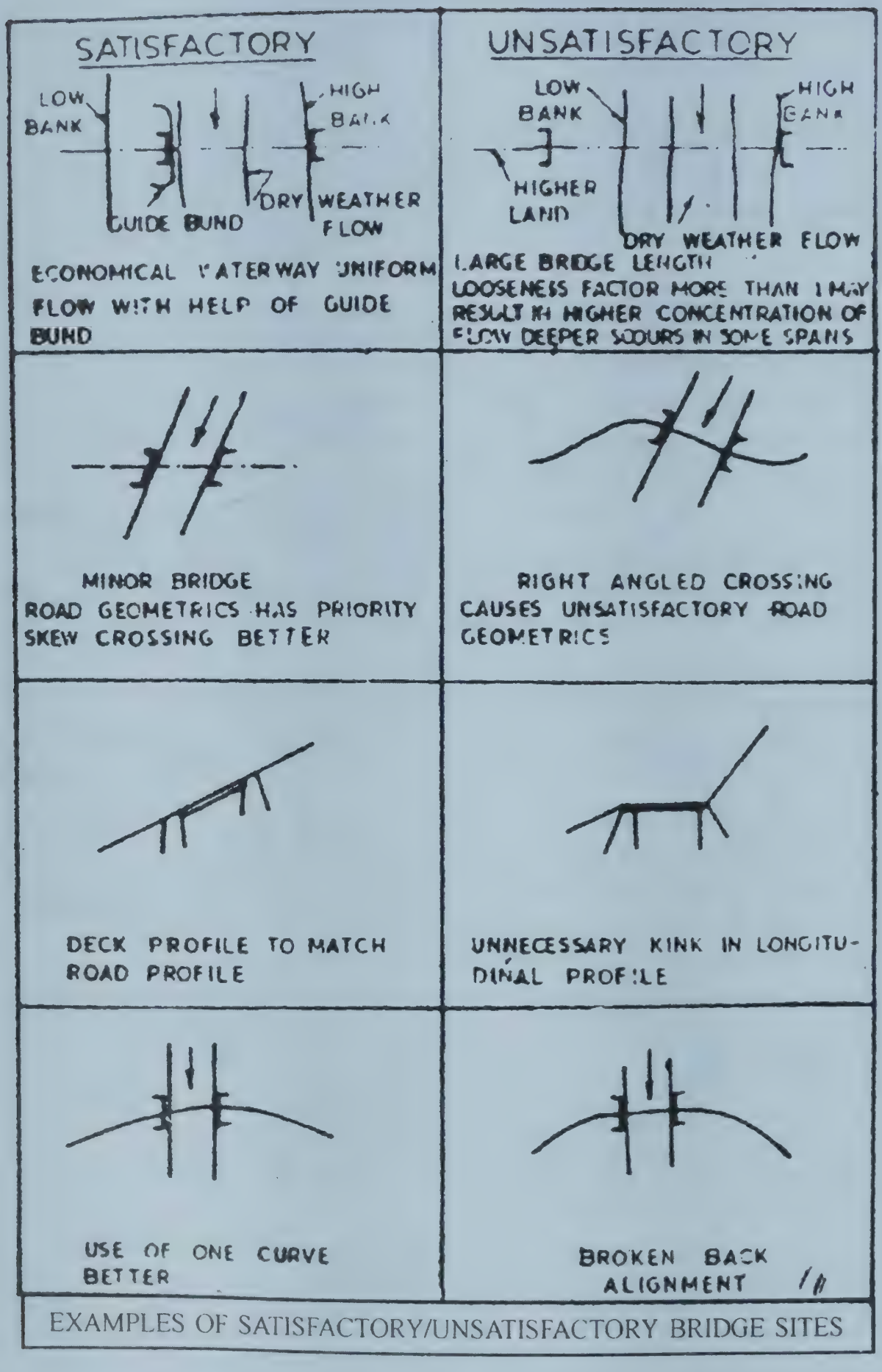
(ii) **Rivers in sub-mountaneous region:** Rivers in this region are characterised by steep slope, high velocity and heavy sediment loads. In Himalayan region, the rivers are shallow with number of independent channels. The allocation of discharge between different channels cannot be predicted with reasonable accuracy. Some channels remain dead during one season and get activated in the next and vice-versa. The banks being low,


SATISFACTORY
UNSATISFACTORY
STRAIGHT REACH
MEANDERING
BRIDGE
H.F.L
O.F.L
DEFINED NARROW CROSS SECTION, HIGH BANK DEPTH UNDER O.F.L COMPARED WITH H.F.L DEPTH HIGH.
H.F.L
O.F.L
WIDE CHANNEL NO DEFINED BANKS LARGE WATER SPREAD BEYOND BANKS O.F.L DEPTH OF FLOW SHALLOW AS COMPARED TO H.F.L DEPTH
LOW LAND
HIGH LAND
BRIDGE SITE SUFFICIENTLY D/S OF JUNCTION OF TRIBUTARY
LOW LAND
BRIDGE SITE TOO CLOSE TO JUNCTION OF TRIBUTARY
NODAL POINT
ROCK OUT CROPS ETC
GOOD SITE JUST D/S OF NODAL POINT
ISLANDS
SITE AFFECTED BY ISLANDS MAY CAUSE OBLIQUITY OF FLOW

EXAMPLES OF SATISFACTORY/UNSATISFACTORY BRIDGE SITES

Fig. 2.2.1

Contd.



EXAMPLES OF SATISFACTORY/UNSATISFACTORY BRIDGE SITES

Fig. 2.2.1

overtopping is quite common and thus intermingling of the discharge from one channel to the other takes place. When a road alignment crosses these channels, waterway provided should be liberal with the provision of extension on either side by adopting abutment piers. To account for unusual deposition of heavy sediment load, larger vertical clearances than those generally specified in the codes of practices should be provided.

(iii) **Rivers in alluvial plains:** In alluvial plains, rivers tend to meander and pose problems in predicting their hydraulic behaviour. Here one should look for nodal points. Also provision of spurs, guide bunds etc. has to be judiciously considered based on opinion of experts and model studies in case of large rivers or based on past experience of the region. If possible sites near existing guide bunds, protected banks or extension thereof should be preferred.

2.2.3.3. **Siting of grade separators:** Siting of bridges which act as rail/road, road/road grade separators will be largely decided by good alignment of the approaches, availability of land and other constraints imposed by rail lines, services etc. At skew crossings, skew of more than 45 should generally be avoided.

2.2.3.4. **Distance between rail and road bridges:** The distance between rail and road bridge should be as large as possible but not less than 400 m in any case.

2.2.4. **Preliminary survey, subsoil investigations and hydraulic survey :** Once the possible alternative sites are selected on the basis of reconnaissance survey and the criteria for site selection enumerated in para 2.2.3 above, the next step is to conduct the preliminary survey, subsoil investigations and hydraulic survey at each of the alternative sites.

2.2.4.1. **Preliminary survey :** The data to be collected during the preliminary survey are:-

(i) The names of the state, district, nearest town/village, and river across which the bridge is proposed.

(ii) The chainage of the highway, location of nearest GTS bench mark with level, and latitude and longitude of the site as measured from the survey of India maps.

(iii) Details of the existing bridges or causeways on the same river in the vicinity which should include

- description with sketches showing relevant dimensions.
- length and depth of submergence, number and sizes of vents, and frequency (including duration) of interruptions to traffic in case of causeways.
- Number and length of spans, clear waterway, adequacy or otherwise of waterway with special reference to silted up spans or signs of undue scour or attacks on abutments and approaches in case of bridges.

(iv) An index map of the site on a scale of 1:50,000' indicating the name and chainage of the highway. The name of the river, name of the nearest town/village marking of the alternative sites, location of the nearest GTS benchmark if possible, name of district and state, direction of flow, nature of land-use, general topography of the area and north line.

(v) Site plans of the bridge for the alternative sites indicating the north line, alignment of the road and the river, the angle of crossing, water spread at LWL/HFL. Chainage of the proposed bridge at crossing of the river, the direction of flow at maximum discharge, private land boundaries, services, location of deep channels, ponds, places of worship, graveyards, if any, near to the proposed site. Location and reduced level of the temporary bench mark used as datum, location of the L.S. and C.S. of the road and the stream taken within the area of the plan, location of trial pits/borings with their identification number and location of nallahs, wells, buildings, rock out crops etc. which may affect the approach alignments.

2.2.4.2. **Hydraulic survey :** Hydraulic data collected for the purpose of the preliminary project report (PPR) has to be good enough for the detailed engineering also. No separate hydraulic data collection is envisaged for detailed engineering except that for model studies, if any, conducted for bridges across major rivers. The hydraulic data collected at PPR stage should include:-

(i) A catchment area map on a scale of 1:50,000 indicating the drainage channels and the land-use pattern including built up areas, barren land, cultivated land, forests, hilly areas etc. and its area in square kilometers. For preparation of the catchment area GTS maps of largest available scale may also be referred for tracing the ridge line.

(ii) HFL ascertained from watermarks, if any, on the permanent objects on the banks supplemented by local enquiry from nearby inhabitants as to the highest flood levels reached during their living memory.

(iii) Information about velocity of flow and presence of floating debris etc. from local enquiry. Velocity of flow is best ascertained during floods by the use of floats by determining the time to traverse two fixed points at measured distance apart.

(iv) In case a causeway or the existing bridge is of insufficient waterway resulting in afflux, the extent of such afflux be ascertained for arriving at the rough assessment of discharge.

(v) Names and approximate discharges of all tributaries joining the river within a reasonable distance u/s of the site under consideration.

(vi) Skew angle of crossing, if any, should be ascertained correctly. Skew angle should be measured in relation to the direction of flow at/near HFL and not in relation to the bank line.

(vii) The approximate depth of the deep scour hole below

HFL mentioning its location, whether general or localised near any hard obstruction or caused by whirlpool. Information about scour around piers and abutments of any other bridge across the same river in the vicinity from records or by soundings taken near the proposed site during receding floods will be very useful in cross checking the calculated scour and thereby avoiding gross errors.

(viii) The khadir width in case of wide/meandering alluvial rivers. The width and depth of the channel during dry weather flow, OFL and HFL should be noted, as well as the radii of the larger meanders scaled from the map.

(ix) Cross section of the river on a vertical scale of about 1/100 and horizontal scale of 1/10000, at the proposed sites indicating

(a) Name of the river and the site
(b) The (road) chainages and bed levels with reference to the temporary benchmark and ground levels for sufficient distance beyond the edge of the channel
(c) Nature of the subsoil in the bed, bank approaches and location of the trial bores.
(d) LWL, OFL and HFL
(e) Low and high tide levels where applicable.

It should also include one or two additional cross sections at 300 to 500 m u/s and d/s for small and large rivers respectively.

(x) A longitudinal section of the stream showing the proposed site, HFL, OFL, LWL and bed levels at suitably placed intervals along the approximate centreline of the deep water channel. The horizontal scale shall be same as for survey plan and vertical scale not less than 1:1000.

(xi) Rainfall data indicating

(a) Maximum precipitation in one hour and 24 hours

(b) Rainfall distribution in catchment
(c) Duration, frequency of floods
(d) Rain gauge data of storms for which corresponding stream gauge data is available (data for unit hydrograph)
(e) Average annual rainfall characteristics (append relevant meteorological records).

(xii) Stream/channel characteristics

(a) Seasonal or perennial
(b) Braided, meandering or straight
(c) Other classifications like bouldery, flashy, well defined, presence of pools, weeds etc.
(d) Highest flood and other major floods and their year of occurrence delineating the areas flooded
(e) Afflux if observed

2.2.4.3. **Preliminary subsoil investigation**

(i) Preliminary subsoil investigations should include adequate number of trial bores/trial pits for obtaining realistic data for deciding the span arrangement, type of foundation and scour level as specified in IRC:78 for making the preliminary design of the bridge. The exploration shall cover the entire length of the bridge and also extend at either side for a distance of about twice the depth below bed of the last main foundations. It should also include study of available information on the geological formations from geological maps, site reports of existing bridges, aerial photography etc. If significant difference in the foundation strata is anticipated, few bores at alternative sites may also be required sometimes, so as to help in the final selection of the site.

(ii) **Depth of exploration:** The depth of exploration should be atleast 1 ½ times the minimum width of the foundation below the proposed foundation level in case of open foundations and deep well foundation. Where such investigation end in any unsuitable or questionable

foundation material, the exploration shall be extended to a sufficient depth into firm and stable soil or rock but not less than four times the minimum depth of foundation below the earlier contemplated foundation level. In case of good sound rock the stipulation of minimum depth may be decreased based on difficulty to conduct core drilling however minimum depth should not be less than 3 metres.

(iii) Depth of exploration for pile foundation should be as per Section 1100 of MORT&H Specifications for Road and Bridge Works and shall not be less than:

(a) 1.5 times estimated length of pile in soil but not less than 15m beyond the probable length of pile.
(b) 15 times diameter of pile in weak/jointed rock but minimum 15 m in such rock
(c) 4 times diameter of pile in sand, hand rock but minimum 3 m in such rock

(iv) The type of bed material e.g. quartz, micaceous, coarse, medium fine etc. in case of sand, stiff, sticky, loose, soft etc. in case of clay, angular, rounded etc. with size in case of boulders, be noted. Preliminary tests to determine the particle size distribution for calculation of scour depth and approximate bearing capacity for preliminary design of foundation may also be carried out.

(v) Presence of rock if any, in the river bed or banks, excessive erosion of any of the banks or hard material jetting out from any of the banks may be noted in particular.

2.2.5. **Design discharge and linear waterway**

2.2.5.1. **Design discharge**

(i) Usually bridges are required to be designed for a discharge corresponding to a flood with a 50 year return period, and only in case of very important bridges that they are to be designed for a flood of 100 year return

period. Normally, in the absence of reliable data for statistical analysis of floods, design discharge may be fixed on the basis of any rational method. Empirical methods are less reliable and may be used with caution. Various methods for calculating discharge are given in *Appendices-1 to 4.*

(ii) **Design discharge by Unit Hydrograph Method:-**
A Committee of engineers set up by the Government of India in 1957 recommended the adoption of rational methodology involving use of design storms and unit hydrographs for the estimation of design floods. As a follow up of recommendations of the committee of engineers, four organisations concerned with the design of bridges (namely Research, Design and Standards Organisation of the Ministry of Railway, Ministry of Road Transport & Highways, Indian Meterological Department and Central Water Commission) have made a joint effort which aims at collection of rainfall, run-off data for a period of about five years in the catchments of small and medium bridges analysing the data and developing a rational methodology based on unit hydrograph. This methodology provides through a set of charts and graphs quick estimation of design fioods for ungauged catchments. For the purpose of detailed study, the country has been divided into 26 hydro meterologically homogeneous sub-zones. The study has been completed and reports have been published for 24 sub-zones.

The methodology as brought out in the above referred report should be followed for estimation of design floods for ungauged catchments. These reports have been published by Central Water Commission and can be had from the Deptt. of Hydrology (Regional Studies), Central Water Commission. A list of the various sub-zones is available at *Annex–1 to Appendix–3.*

The method recommended in the report of the relevant sub-zone pertaining to that subzone may be followed for assessment of maximum discharge for the design of

bridges. As an example, the method for estimation of design discharge for a typical basin is enclosed at *Annex–2 to Appendix–3* for guidance.

(iii) Freak flood discharges or exceptional discharges of high intensity due to the failure of a dam or tank constructed upstream of the bridge need not be catered for and the maximum estimated discharge from the catchment area or normal peak flood discharge from the dam/spillway (to be ascertained from the irrigation authorities), whichever is more shall be considered for design of the bridge.

(iv) In case of bridges across rivers not having well defined independent catchment, the following considerations shall also be kept in view.

(a) In case of a river dividing into two or more branches, the apportioning of the discharge of the combined river u/s between the branches, the HFL's at the proposed bridge site etc. may be decided in consultation with irrigation and flood protection authorities.

(b) The vulnerability or stability of the existing flood banks based on past performance may be ascertained from irrigation authorities and duly taken into account for deciding the design discharge, HFL's higher than design values, free board etc.

(v) In case the river is likely to be influenced by existing/ proposed irrigation multipurpose river valley projects, their operation modes with effect on scour or silting, discharge, backwater effect on HFL etc. should be ascertained.

(vi) However, for catchment areas covered by subzones mentioned in *Appendix-3A*, the maximum discharge shall be assessed on the basis of the flood estimation report for the said subzone.

(vii) The design discharge arrived at from hydraulic calculations or from gauging shall be increased for the purpose of design of foundations and protective works by 30 per cent for small catchments upto 500 sq. kms 25 to 20 per cent for medium catchments of 500 to 5000 sq. kms, 20 to 10 per cent for large catchments of 5000 to 25000 sq. kms and less than 10 per cent for larger catchments above 25000 sq. kms.

2.2.5.2. **Linear waterway**

(i) For rivers with defined firm banks, the linear waterway is preferably kept equal to the HFL spread at the site. However, when the depth of flow near the banks is low in comparison with deep channel portion, constriction of the waterway upto 2/3rd of the HFL spread is resorted to from considerations of economy. But careful consideration has to be given on the possibility of excessive scour of the banks or bed on the d/s of the bridge or of excessive afflux on the u/s before deciding on any constriction of waterway.

(ii) The likely mean depth and velocity of flow shall be the main guiding factors for deciding the linear waterway to be provided for any bridge. Here for effective functioning of the waterway, afflux of 10 to 30 cms may be allowed with due consideration for any possible adverse effects on the upstream.

(iii) For rivers with alluvial beds and no defined banks, the effective linear waterway can also be derived from the formula $W = C\sqrt{Q}$, where C is a constant usually taken as 4.8 for regime channels, but varying between 4.5 to 6.3 according to local conditions. The formula should be used judiciously only after ascertaining the soil characteristics in the river bed and the regime of the river.

(iv) For meandering rivers with several active channels separated by islands or shallow sections, it may become

necessary to considerably restrict the waterway by providing training works. The design of the training works and the effective linear waterway are to be preferably based on model studies.

(v) For artificial channels, the effective linear waterway has to be maintained so as not to increase the velocity. Any fluming or higher velocity should have the approval of the concerned authorities.

(vi) The effective linear waterway may be compared with that provided under other bridges in the vicinity over the same river after duly considering their performance.

2.2.6. **Scour depth**

2.2.6.1. Wherever feasible, depth of scour shall be assessed on the basis of actual soundings taken at the proposed site or near it during the receding phase immediately after high flood conditions with necessary allowance for:-

(i) the design discharge being higher than the one for which observations have been made

(ii) the increase in velocity due to constriction of waterway.

2.2.6.2. In the absence of actual soundings the mean depth of scour dsm in metres below HFL may be theoretically calculated from the equation:-

$$dsm = 1.34\ (D^2b/Ksf)^{1/3}$$

Where *Db* is the discharge in cumecs per metre width which shall be taken as maximum of the following:-

(i) total design discharge divided by the effective linear waterway

(ii) discharge per meter calculated after considering concentration of flow, if any, through a portion of the waterway in case of major bridges, or

(iii) actual observations, if any

and *Ksf* is the silt factor which is equal to 1.76 $\sqrt{dm}$; dm being the weighted mean diameter of the representative sample of the bed material upto the anticipated scour level. In the absence of sieve analysis, IRC:78 prescribes following values of silt factors.

Type of bed material	dm weighted mean diameter of particle in mm	Value of '*Ksf*' silt factor
Fine silt	0.081	0.500
Fine silt	0.120	0.600
Fine silt	0.158	0.700
Medium silt	0.233	0.850
Standard silt	0.323	1.000
Medium sand	0.505	1.250
Coarse sand	0.725	1.500
Fine bajri and sand	0.988	1.750
Heavy sand	1.290	2.000

2.2.6.3. For the design of foundation of piers and abutments located in the straight reach and having individual foundations without protection works, the maximum depth of scour shall be considered as follows:-

(i) in the vicinity of piers = 2.00 dsm

(ii) in the vicinity of abutments = 1.27 dsm when approaches are retained and 2.00 dsm when approaches are washed off

2.2.6.4. For the design of floor protection measures and for

raft or shallow foundations, the maximum depth of scour shall be considered as follows:-

(i)	in straight reach	=	1.27 dsm
(ii)	at moderate bend	=	1.50 dsm
(iii)	at severe bend	=	1.75 dsm
(iv)	at right angled bend	=	2.00 dsm

The above values of scour may be suitably modified where actual observed data is available on similar structures in the vicinity of the proposed bridge.

2.2.6.5. In case of flashy rivers and bouldery strata the scour is likely to be less than what is given by the formula. In such cases, scour depths may be based on actual observations.

2.2.6.6. For bridges proposed d/s of a reservoir, the clear water will have higher scouring effect and in such cases also, scour depths shall be based on actual observations.

2.2.6.7. For seismic case, scour to be considered in design shall be 0.9 times the maximum design scour depths.

2.2.7. **Afflux**

2.2.7.1. Afflux is the height by which the natural flood level of the river rises at any point due to constriction and / or obstruction. It has to be estimated not only for its effect on the design of the bridge, but also to ensure that it may not adversely affect condition on the upstream of the bridge site. The type of bed and bank material and the type of bridge influences the extent of afflux. Constriction of channel on account of flood banks, guide bunds, piers, floor protection etc. increases afflux. Afflux is high in flashy rivers as well. Afflux may be calculated approximately using Molesworth formula as given below:-

$$h = (V^2/17.88 + 0.015)\ \{(A/a)^2 - 1\}$$

where h = afflux in metres

V = average velocity of the water in the river prior to constriction in m/sec.

A = Unobstructed sectional area of the river at proposed site in sq.m.

a = Constricted area of the river at the bridge in sq.m.

For guidance IRC Special Publication No. 13 may also be referred to for calculation of afflux.

2.2.8. Clearance

2.2.8.1. Vertical clearance above H.F.L.

(i) Clearance shall be allowed according to navigational or anti-obstruction requirements in consultation with the concerned authorities. For inland waterways, Inland Waterway Authority has framed regulation for classification of inland waterways in India and has recommended minimum clearance for various categories of waterways which is placed at *Appendix–5*. The clearances as referred above may be followed in consultation with Inland Waterway Authority, wherever required. Where these considerations are not applicable, the vertical clearance shall ordinarily be adopted as given below:-

(ii) For high level bridges having flat soffit or soffit with a very flat curve, the minimum vertical clearance to be provided above affluxed HFL shall normally be as follows:-

Discharge in cumecs	Minimum vertical Clearances in mm
Upto 0.3	150
Above 0.3 and upto 3	450
Above 3 and upto 30	600
Above 30 and upto 300	900
Above 300 and upto 3000	1200
Above 3000	1500

Note: The minimum clearance shall be measured from the lowest point of the deck structure inclusive of main girder in the central half of the clear opening unless otherwise specified.

(iii) Vertical clearance may be increased based on navigational requirements or where the chances of having floating debris like trees are high.

(iv) For arched openings of high level bridges having overhead decking, the clearance below the crown of the intrados of arch shall not be less than one tenth of the maximum depth of water plus one third of the rise of the arch intrados.

(v) In bridges provided with metallic bearings, no part of the bearing shall be less than 500 mm above the affluxed HFL.

(vi) In case of bridges in sub-mountainous region, the possibility of silting of the river bed may also be considered while fixing the vertical clearance.

(vii) Difference between deck level and affluxed HFL shall not be less than 1.75 m to safeguard road crust in approach embankment against capillary action of water.

2.2.8.2. **Clearance for traffic**

(i) The minimum vertical and horizontal clearances (clear height and width respectively available for passage of traffic) to be provided on bridges shall be as specified in IRC-5.

(ii) For bridges constructed on horizontal curve with super elevated road surface, the horizontal clearance shall be increased on the side of the inner kerb by a margin equal to 5 metres multiplied by the super elevation; the maximum vertical clearance being measured from the super elevated level of the roadway. The above extra horizontal clearance required is over and above the

increase in width required for the design of road on curve.

(iii) For footways and cycle tracks, the minimum vertical clearance shall be 2.25 metres.

(iv) For vertical and horizontal clearances at under passes and / rail over bridges the essential provisions are given below. IRC:5 may be referred to for details.

(a) Lateral clearance at under passes
Desirably the full roadway width of the approaches should be carried through the under pass. See IRC: 54 for more details.

(b) Vertical clearance at under passes

Rural areas	–	5 m min
Urban areas	–	5.5 m min.

(c) Vertical clearance for railway traction (broad gauge)

Electric traction	–	5.87 m min.
Non-electric traction	–	4.875 m min.

(d) Vertical clearance for power/telecommunication lines

Lines carrying low voltage upto 110 v	–	5.5 m min.
Electric power lines upto 650 V	–	6.0 m min.
Electric power lines > 650 V	–	6.5 m min.

2.2.9. **Width of carriageway, footpath and median**

2.2.9.1. **General (for all roads except national highways) :** The provisions given in clause 112 of IRC:5 may be applied for all bridges except for National Highways for which para 2.2.9.2 may be referred to.

(i) The carriageway width shall not be less than 4.25 m for single lane bridge and 7.5 m for 2 lane bridge, which shall be increased by 3.5 m for every additional lane of traffic for a multiple lane bridge. In addition, the cross section of 2 lane and multi lane bridges shall satisfy the following:-

(a) For **minor bridges** of total length upto 60 m: The overall width (or width between outer most faces of the bridge) shall be equal to the roadway width of approaches subject to a minimum of 10 m for hill roads other district roads and 12 m for other cases.

(b) For **major bridges**: For urban situations, the overall width shall be equal to the roadway width of the approaches. For non-urban situations, the width of the bridge shall provide for 7.5 m carriageway plus a minimum of 1.5 m wide footpaths on either side, wherever required.

(ii) For multi-lane bridges, the overall width shall be the same as the roadway width of the approaches, the width of the median in portion being kept the same as in the approaches. Wherever footpaths are provided, their width shall not be less than 1.5 m.

(iii) For bridges on horizontal curve, the roadway width shall be increased suitably to conform to the requirements stipulated in the relevant IRC Road standards.

(iv) When a footpath is provided, its width shall not be less than 1.5 metres. For urban and populated areas having large concentration of pedestrian traffic, the width of the footpath shall be suitably increased.

2.2.9.2. **For bridges on National Highways :** All bridges should have width between outer most faces of the railing kerbs equal to the roadway width of the approaches irrespective of their length or location. For details, Ministry's Circular No. RW/NH-33044/2/88-DO.II dated 09/05/2000 may be referred to. The broad provisions of the circular are as given below:-

(1) **New Bridges and those being reconstructed on 2 lane National Highways:** Overall width between outer most faces of the railing kerbs shall be equal to the full roadway width of the bridges subject to a minimum of 10 m for hill roads and 12 m for other cases.

(2) **Existing bridges on two-lane National Highways:** For, bridges on 2 lane National Highways being improved by way of provision of 1.5 m paved solders on either side, widening of the existing bridge, wherever feasible, should as far as possible be done simultaneously and cross sections on the bridges and approaches should match each other.

(3) **New bridges on 4 lane National Highways:** On 4 lane National Highways, the overall width of the bridge deck shall be equal to the roadway width of the approach road with distance between the inner kerb lines in the median portion equal to the median width of the approaches. Normally, the total width shall be 24 m between the outer most faces of the railing kerbs.

(4) In case of 4 lane National Highways if additional 2 lane bridge is being constructed parallel to the existing 2 lane bridges, for the additional 2 lane bridge the total width shall be 9.75 m between inner face of the median/ right railing kerb and the outer face of the left railing kerb with unidirectional cross slope / camber. If feasible, the existing 2 lane bridge may also be widened to 9.75m.

(5) For multi-lane bridges with 6 lanes, 8 lanes etc., the overall width between the outer most faces of the railing kerb of the bridge shall as far as possible be the same as the full roadway width of the approaches.

(6) It is preferable to have two independent bridges for each direction of traffic for all 4 lane and other multi-lane bridges.

(7) Width of the median in the bridge portion shall as far as possible be kept the same as that of the approaches. In case width of median is different from that of the approach section due to site constraints, proper transition and safety measures may be provided over the approaches as per Ministry's Circular No. RW/NH-33022/1/94-DO.III dated 24/06/94.

(8) **Footpaths:** In urban areas, minimum footpath width of 1.5 m may be provided. In case of divided carriageways, footpath shall be provided only on the left side of the carriageway for each direction of traffic. Wherever footpath is not provided, safety kerb of 750 mm width has to be provided as per Clause 111.3 of IRC:5. In case of very high volume of pedestrian traffic, the provision of footpaths of more than 1.5 mt width or a separate pedestrian bridge may be considered depending on site conditions.

(9) **Crash Barriers:** Crash barriers shall be provided for all bridges on National Highways to safeguard against errant vehicles. For bridges with footpath, crash barrier shall be so located as to separate the main carriageway from the footpath for the safety of pedestrians. For further details, IRC-5 "General Features of Design" may be referred to.

(10) **Extra width on curves:** In case of bridges lying on a curve or a horizontal profile, extra width on bridge shall be provided as per IRC codal provisions applicable for road section.

2.2.10. Fixation of span arrangement and selection of the type of structure

2.2.10.1. **General consideration in selection of type of bridges and span arrangement:** Specific site characteristics like width of crossing, nature of stream, depth of flow during different seasons, subsoil characteristics, and the capabilities of contracting agencies who would be interested in building the structure including availability of skilled and unskilled labour are mostly the major considerations in selecting the type of structure and span arrangement in specialised structures like long span bridges. The attempt of the engineers should be towards minimising the overall cost of the total structure including approaches within the site specific constraints as obtained. For normal simply supported structures, it has been observed that the total cost of the bridge proper tends to be the minimum, when the cost of superstructure approaches to that of

foundation and substructure put together which may be applied as a thumb rule for initial trial.

2.2.10.2. **Aesthetic and environmental considerations**: Aesthetics and environmental considerations are increasingly becoming major factors in the selection of the type of structure including its foundation to be adopted for a specific site. To achieve aesthetically pleasing view of bridge structure, attention should be paid to produce a clean, simple, well proportioned structured form. In most cases, achieving the desired structural quality may add little to the overall cost of structure. Aesthetic considerations include harmony with the general topography of the site, optimisation in the use of materials etc. Environmental considerations include limitation of noise levels and during and after construction of the bridge and the level of pollution due to air and water during construction and service, conservation of flora and fauna etc.

2.2.10.3. **Guidelines on aesthetics**: A few important characteristic elements to bridge aesthetics are cited below. These involve some fundamental aspects and lay down the basic principles of good aesthetic design. The basic knowledge of these aesthetic principles is essential to all levels of bridge design and management. Reference to specific literature for elaborate self-study is recommended.

(1) **Proportion:** Proportion (Harmony) is classified into 3 principle systems:-

(a) Arithmetic Proportion – 1/3, 1/9 etc.
(b) Harmonic Proportion – a/b = c/d etc.
(c) Geometric Proportion i.e. equilateral/isosceles/ Egyptian triangle.

Harmony in proportion is a primary aesthetics consideration and termed as the first order aesthetic dimension. In relation to bridges, proportion may pertain equally to structure, environment ensemble, the structure total or elements of the structure. Proportion between linear dimension like length, width, and height between masses and voids between areas in light and shadow etc. are to be considered important.

(2) **Contrast:** As opposed to harmony in proportion, contrast can heighten values of some elements in comparison with others. A contrast of volumes, surfaces or linear dimensions, a contrast in materials and their colour, a contrast of light and shadow etc. are the aspects to be kept in view.

(3) **Scale:** The absolute real dimensions of the structure defining its scale play a dominant role in aesthetic study. The quality of bridge structure is judged from the different points of view like compatibility with its environment or compatibility with its constituent elements.

(4) **Order:** Order in bridge structure is the key aesthetic quality. Order in line is achieved by limiting their directions in space to the minimum practicable. Symmetry in proportion and shape is an important element of order. Repetition of shapes, lends an order which provides rhythm. However, when overdone, it can lead to monotony which has to be avoided. Simplicity and cutting down unnecessary accessories will lead to a good order.

(5) **Character:** The character of a bridge structure as an element of the man made environment is expressed by its effect on the humans using it. The desired character is determined by societal objectives which may vary. The structure today needs to reflect technological excellence and look modern, but this should stimulate qualities of buoyancy and relaxation.

(6) **Colour**: Colour has a significant aesthetic effect. In bridges with concrete as the most used material, the choice is limited. However, the surface texture, weathering quality etc. have added importance in this context which has to be kept in view for aesthetic considerations.

(7) **Functionalism:** In bridges form follows function. Functional efficiency never conflicts with form. It generates simplicity in form and aesthetic quality, given the attention due to it. Added ornamentation like a stone facing to hide concrete or redundant pylons, pilasters or arches is irrelevant to modern bridge forms. Ornamentation of large surfaces of piers, abutments, retaining walls by suitable treatment or texturing can enhance the aesthetic quality and character of bridges especially in urban environment. These potentials should be recognized and made full use of.

(8) **Environmental integration**: The integration of the bridge structure with the environment is the most important aesthetic need of the modern bridges. Simplicity in form may suit open rural lands. Wide river crossings may demand bridges with character compatible with the majesty of the river, structure built in urban or metropolitan environment should have special aesthetic qualities because of their large impact on people and their habitat.

(9) **Complexity**: Complexity belongs to the second order aesthetics. The Complexity rightly used can build tension with subsequent release and produces a pattern more dynamic than static. It has application potentials in bridge design specially in case of large structures.

(10) **Third order aesthetics**: Intuitive, artistic sensibility of artistically gifted designer can build beauty in structures including bridges. Obviously, this higher level aesthetics combine the first and second order characteristics of harmony and complexity; something more is added to produce elegance.

2.2.10.4. **Economical range of span lengths for different types of superstructures**: Apart from the estimated cost based on schedule of rates, costs as quoted during tendering may be used for constantly updating the cost analysis data. The ranges of span length

within which a particular type of superstructure can be economical along with other considerations like type of foundation etc. are given below:-

(i)	R.C.C. single or multiple boxes	-	1.5 to 15 m
(ii)	Simply supported RCC slabs	-	3 to 10 m
(iii)	Simply supported RCC T beam	-	10 to 24 m
(iv)	Simply supported PSC girder bridges	-	25 to 45 m
(v)	Simply supported RCC voided slabs	-	10 to 15 m
(vi)	Simply supported/continuous PSC voided slabs	-	15 to 30 m
(vii)	Continuous RCC voided slabs	-	10 to 20 m
(viii)	RCC box sections; simply supported / Balanced cantilever continuous	-	25 to 50 m
(ix)	PSC box sections; simply supported / Balanced cantilever	-	35 to 75 m
(x)	PSC cantilever construction / continuous	-	75 to 150 m
(xi)	cable stayed bridges	-	100 to 800 m
(xii)	Suspension bridges	-	300 to 1500 m

However, whenever an economical span arrangement and type of structure is decided, it has to be ensured that the required infrastructural facilities, design and construction capabilities, specialised materials etc. are available.

2.2.10.5. **Type of foundations:** The subsoil characteristics obtained at a particular site and consequently the type of foundations feasible, is one of the major considerations in selection of type of structure and span arrangement as already mentioned.

(i) **Shallow foundations**: Isolated open foundations are feasible where an SBC of about 15 t/m^2 or more is available at shallow depths with in-erodible substratum. Here again, open excavation is feasible only upto a depth of 3 to 4 m where the subsoil is porous and water table is high. In cases, where the SBC is still less and where smaller spans are economical from other considerations, raft foundations or box structures with floor protection and curtain walls are the other options.

(ii) **Deep foundations** : Where suitable founding strata is available at a depth of 6 m or more with substantial depth of standing water, highly pervious substratum and large scour depth, it may be advisable to go for deep foundation like (a) well, or (b) piles.

(a) **Well foundations**: This is one of the most popular types of deep foundations in our country, due to various reasons like its simplicity, requirement of very little of equipment's for its execution, adaptability to different subsoil conditions and difficult site conditions like deep standing water and large depths to good founding strata. Caissons are an adaptation of well foundations to sites with deep standing water.

(b) **Pile foundations**: Pile foundations are another type of deep foundations which are suited for adoption in the following situations:-

Availability of good founding strata below large depth of soft soil.

Need to have very deep foundations beyond the limit of pneumatic operations usually depth beyond 35 metres or so.

In some cases of strata underlying deep standing water and the strata being very hard not permitting easy sinking of wells or based on economic factors deciding the use of piles as compared to wells. However, pile foundations are not preferred within the flood zone of the river with deep scour.

(iii) **Classification of piles**

(a) Precast driven piles
(b) Driven cast-in-situ piles
(c) Bored cast-in-situ piles
(d) Bored precast piles and
(e) Driven steel piles

Further guidance on the design and construction aspects of pile foundations can be obtained from IRC:78.

2.2.10.6. **Allowable bearing pressure**

(a) There are two limits for allowable bearing capacity, one based on considerations of strength of the subsoil to support the superimposed load without suffering failure/ rotation and the other based on allowable settlement due to short term or long term consolidation, the latter being more significant in case of cohesive soils.

(b) Allowable bearing pressure and settlement shall be calculated based on the test data available from the preliminary subsoil investigations, provisions contained in IRC:78 and the relevant Indian Standards mentioned therein.

(c) In hard rock bearing pressure exceeding 2 MPa is normally not permitted. For very soft and highly disintegrated rock allowable bearing pressure may be assessed using methods prescribed for soils.

(d) **Safe load carrying capacity of piles**: It shall be lesser of the two values:

(i) Ultimate load carrying capacity based on the soil parameters surrounding the pile divided by a suitable factor of safety.

(ii) Structural strength of the pile.

These shall be assessed as follows:-

(i) Ultimate load carrying capacity:
Static formula (based on soil data)

$Ru = Rb + Rf$

where Ru = Ultimate load carrying capacity
Rb = Ultimate base resistance
Rf = Ultimate side resistance

$Rb = Ab \times fbu$

where Ab = plan area of base of pile
fbu = ultimate bearing capacity of the soil at the pile base per unit area

and $Rf = \sum Asi \times fsi$

where Σ = Summation of 'n' layers in which the pile is installed

Asi = the surface area of the pile in a particular strata

fsi = average skin friction or adhesion per unit area of the pile for that particular strata

For working out safe load carrying capacity of the pile, a factor of safety of 2.5 shall be adopted.

(ii) **Structural strength of piles:**

The structural strength of a pile shall be assessed based on its axial and lateral load capacity (refer IRC:78)

Axial capacity: where a pile is wholly embedded in a soil of undrained shear strength not less than 10 KPa, its axial strength is not limited by its strength as a long column. For piles driven through very weak soils having strength less than 10 KPa, suitable reductions shall be made in its structural strength taking into account the buckling phenomenon, for which guidance may be taken from specialised literature. When the pile projects above ground level, the effective length shall be governed by the fixity conditions imposed by the structure it supports and the nature of the surrounding soil mass. The depth of the point of contraflexure below the ground varies with the type of soil. In good soil, the lower point of contraflexure may be taken at a depth of 1 metre below ground surface subject to a minimum of 3 times the diameter of the shaft. In weak soil of undrained shear strength less than 10 KPa, such as soft clay or soft silt, this point may be taken at about half the depth of penetration into such stratum but not necessarily more than 3 m. A stratum of liquid mud shall be treated as water. The degree of fixity of position and inclination of the pile top and restraint provided by any bracing shall be estimated in accordance with accepted normal structural analysis.

Lateral load capacity: The effect of other co-existant

loads and forces, including axial loads shall be considered alongwith the lateral loads. The lateral load carrying capacity of a pile depends upon horizontal sub-grade modulus of the surrounding soil and its structural strength against bending.

Where vertical piles cannot resist the applied horizontal forces, raker piles may be provided. The distribution of loads and forces between the rakers and the verticals in a group be determined by graphical or analytical methods. Effects of pile cap movement, bending due to self weight of pile in loose soils inducing secondary bending shall also be considered.

2.2.11. **Preliminary design of various components of bridge**

2.2.11.1. The preliminary design should include all calculations needed for finalising the cross section of the superstructure including the checks for the maximum bending stress and shear stress. It should also include preliminary design of the critical abutment and pier on the basis of preliminary subsoil investigations.

2.2.11.2. **Minimum depth of foundations**: The following minimum depths may be ensured:

(i) **Shallow foundations in erodible strata**: Such foundations may be taken to a minimum depth of 2.0 m if they support an arch superstructure or 1.20 m in other cases provided adequate SBC is available at that depth to support a individual foundation or rafts as the case may be and the foundations are protected against undermining by suitably designed flooring, cut off walls and launching aprons.

(ii) **Deep foundations in erodible strata**: Such foundations shall be taken to such depth where the base pressures calculated based on any rational design method is less than the available S.B.C. and a minimum grip length of 1/3rd of the maximum anticipated scour depth below HFL (i.e. 1/3rd of 2d) is ensured.

(iii) **Shallow foundations in rock**: A minimum embedment of 0.6 m in case of hard rocks having a crushing strength of 100 kg/cm^2 or more may be provided considering the overall characteristics such as fissures, bedding planes, cavities etc. Higher embedment may be provided for softer varieties considering the above mentioned characteristics and strengthening measures, if any, proposed.

(iv) **Deep foundations in rock**: If hard rocky strata is met with at depths below the maximum scour level, and if deep foundations are resorted to, it shall be ensured that such foundations are evenly seated all along the periphery on sound rocky strata (devoid of fissures, cavities, weathered zones etc). On sloping rock surfaces, the foundations shall be properly seated by benching and the extent of seating and embedment in each case shall be decided by the Engineer-in-charge.

2.2.11.3. **Minimum requirements, checks for stresses and factors of safety for foundations:** All foundations shall be designed to carry the loads and forces specified in IRC:6 subject to combinations, allowable stresses/pressures and factors of safety specified in IRC:78. Normally, no tension is permitted at the base under any combination of loads and forces, and the maximum base pressure should be less than the calculated allowable bearing pressure. However, tension area may be permitted on rock upto 20 per cent of the base area provided the foundation pressure calculated on the net area of contact after redistribution is less than the allowable bearing pressure. For foundations on clayey soil, the base pressure under permanent loads shall be as uniform as possible to avoid possibility of differential settlement or progressive failure.

(1) **Open foundations**: These can be either isolated, combined, strip footings or raft foundations.

(a) **Isolated combined or strip foundations**: All these foundations shall be checked for base pressure, sliding and overturning. Other factors to be taken care of in case of such foundations are:

(i) In case two adjoining foundations are at different levels, the horizontal distance between them shall be adequate for the type of subsoil obtained so as not to cause any distress to the existing foundation during construction or afterwards due to overlapping of the foundation pressure zones.

(ii) In case of plain concrete, brick or stone masonry footing, load from the pier or column shall be taken as dispersed through the footing at an angle not exceeding 45°.

(iii) For reinforced concrete footings, the design shall satisfy the relevant provisions of IRC:21.

(iv) The minimum thickness of footings shall not be less than 300 mm.

(b) **Raft foundations:** Raft foundations can either be in P.C.C. or R.C.C. but with the minimum grade of concrete for structural members being progressively revised upwards, RCC rafts be preferred considering economy. The following aspects have to be taken care of while providing raft.

(i) The design of the raft shall be based on the assumption that it is resting on elastic soil medium and guidance may be taken from IS:2950 (Part-I) for calculation of base pressures.

(ii) The protective works are to be completed before the floods so that the raft foundation do not get undermined.

(iii) For laying the foundation concrete by dewatering, either a trench be excavated all along the periphery of the foundation pit so that water level is kept below founding level or water table is depressed by resorting to pumping.

(iv) For laying foundation concrete underwater tremie pipe should be used. In case of flowing water or artesian springs, the flow shall be stopped or reduced as far as possible and no pumping shall be done during placement of concrete or upto 24 hours after it.

(c) **Additional points to be taken care of in case of open foundation**:

(i) Protective works, if any, shall be completed before monsoon so that foundations do not get undermined.

(ii) Excavation for laying the foundation shall be carried out in accordance with Section 300 of MOST specifications for road and bridge works. The last 300 mm of excavation shall be done just before laying of lean concrete below foundation.

(iii) In the event of excavation having been made deeper than that shown on the drawing or as ordered by the Engineer, the extra depth shall be made up with M15 concrete in case of foundation resting on soil and foundation grade concrete for foundations in rock.

(iv) All spaces excavated and not occupied by the foundation or other permanent works shall be refilled with earth upto surface of surrounding ground in accordance with Section 300 of MOST specifications for road and bridge works. In case of excavation in rock, the annular space around foundation shall be filled with M15 concrete upto the top of rock.

(2) **Deep foundations**: Minimum requirement for (a) well foundations and (b) pile foundations are given hereunder:-

(a) **Well foundation** : Design of sections and stability of well foundations shall be checked in conformity with Clause 710 of

IRC:78. However, some important features are given below for guidance.

(i) The minimum dimension of any dredge hole shall be 2.00 metres

(ii) The grade of concrete for P.C.C. well steining shall not be less than M15 with minimum cement content of 250 kg/m^3 and water cement ratio not more than 0.45. In case of severe condition of exposure, concrete in steining shall not be less than M20.

(iii) The diameter of PCC/RCC wells shall not exceed 12 metre.

(iv) Use of cellular steining or composite material in steining shall not be permitted.

(v) The minimum thickness of steining shall not be less than 500 mm for normal conditions and 1 m for severe conditions of exposure and shall satisfy the following relationship.

$$t = Kd \sqrt{l}$$

where t = minimum thickness of steining in metres
d = external diameter of circular well or dumbwell Shaped well or the smaller dimension in plan of Double 'D' wells in metre
l = depth of well in metre below L.W.L. or ground level whichever is higher

K = a constant.

The value of K shall be as follows:-

(i) Well in cement concrete $K = 0.03$
(ii) Well in brick masonary $K = 0.05$
(iii) Twin D wells $K = 0.039$

The minimum steining thickness may be varied from the above in the following conditions:-

Sl. No.	Strata	Variation from the minimum	Recommended variation
1.	Very soft clayey strata	Reduced	10%
2.	Hard clayey strata	Increased	10%
3.	Boulder strata or well resting on rock involving blasting	Increased	10%

Note: (1) For bouldery strata or for wells resting on rock where blasting may be involved, higher thickness of steining, better grade of concrete, heavier reinforcement, use of steel plates in the lower portions etc. may be adopted as directed by the Engineer – in – charge.

2. For wells passing through very soft clayey strata, the steining thickness may be reduced based on local experience and in accordance with the decision of the Engineer – in – charge to prevent the well penetrating by its own weight. In such cases, the steining may be adequately reinforced to get sufficient strength.

(vi) If specialized methods of sinking such as jack down methods, are adopted, then the steining thickness may be adjusted according to design and construction requirements.

(vii) Where nominal steel is provided in steining, the same shall not be considered in the design for strength.

(viii) For plain concrete well, the reinforcement (either mild steel or high yield strength deformed bars) shall not be less than as indicated below:-

Vertical reinforcements: 0.12 per cent of gross sectional area of actual thickness of steining provided and distributed equally on both faces of the steining.

Hoop reinforcement: 0.04 per cent of the volume per unit length of steining.

(ix) R.C.C. wells shall be designed as R.C.C. columns for combined axial load and bending. The reinforcements arrived at shall, however, be not less than as indicated below:-

Vertical reinforcement: 0.2 per cent (for either mild steel or deformed bars) of actual gross cross-sectional area of steining of which at least 0.06 per cent of gross area shall be on inner face.

Hoop reinforcement: 0.04 per cent of the volume per unit length of steining.

(x) Mild steel cutting edge of weight not less than 40 kg/ metre shall be provided properly anchored to the well curb. In case of wells with two or more compartments, the lower end of the cutting edge of middle stem shall be kept 300 mm above that of the outer walls to prevent rocking.

(xi) The well curb shall be of reinforced cement concrete of grade not lower than M 25 with minimum reinforcement of 72 kg/m^3 excluding the bond rods of steining.

(xii) For the likelihood pneumatic sinking, the internal angle of the well curbs shall be made as steep as possible.

(xiii) Where blasting is anticipated, the inner faces of the well curb shall be protected with steel plates of thickness not less than 10 mm thick upto top of well curb. If it is desired to increase the steel lining above the well curb then the thickness can be reduced to 6 mm for this increased height, which in any case should not be more than 3.0m. The steel plates shall be properly anchored

to the curb and steining. The well curb shall be provided with additional hoop reinforcement of 10 mm dia M.S. or deformed bars spaced at 150 mm centres which shall also extend upto a height of 3 metres into the well steining above the curb.

(xiv) Bottom plug shall be provided in all wells extending upto 300 mm above the well curb with a concrete mix using minimum cement content of 363 kg/m^3 and a slump of about 150mm. Where grouted concrete (colcrete) is used, the grout mix shall not be leaner than 1:2.

(xv) Filling of the well, if considered necessary, shall be done with sand or excavated material free of organic matter.

(xvi) A top plug 500 mm thick in c.c. with grade M 15 shall be provided over the filling.

(xvii) The bottom of the well cap shall be laid preferably as low as possible taking into account of the water level prevalent at the time of casting. Top surface of well cap should be provided below bed level if L.W.L. is very low.

(xviii) All designs shall account for a tilt of 1 in 80 and shift of 150 mm in the resultant direction.

(b) **Pile foundations**: The following general requirements shall be satisfied in the design and construction of piles:

(1) **Spacing of piles**

(a)	Friction piles	-	Centre to centre spacing not less than perimeter of the pile.
(b)	End bearing piles	-	Centre to centre spacing not less than twice the least width of pile

(2) **Size of concrete piles**

- (i) Preferably not less than 0.75 m diameter or equivalent area for bridge foundations in major rivers.
- (ii) Not less than 0.3 m diameter for other locations viz. Wing walls, foundations for flyovers, etc.

(3) **Rake in piles**

The maximum rake to be permitted shall not exceed the following:-

(i) 1 in 6 for all bored piles
(ii) 1 in 6 for driven cast in situ piles; and
(iii) 1 in 4 for precast driven piles

(4) **Tolerance for piles**

(i) for vertical piles 75 mm at piling platform level and tilt not exceeding 1 in 150.

(ii) For raking piles tolerance of 1 in 25 for rakes upto 1 in 6 suitably increased for greater rakes.

(iii) Where raking piles are installed from a level significantly different/higher to the ground level, then the 75 mm lateral tolerance mentioned in (i) above shall be suitably increased due to effect of error in the rake.

(5) **Pile cap**

All pile caps shall be reinforced and their size fixed taking into consideration the allowable tolerance mentioned in sub-clause 4 above. A minimum off-set of 150 mm shall be provided beyond the outer faces of the outermost piles in the group. For piles cap resting on earth, a levelling course of minimum 100mm thickness of M 15 nominal mix concrete shall be provided. The

attachment of the pile head to the cap shall be adequate for transmission of loads and forces. All piles shall be stripped off at top and reinforcement anchored into the cap such that at least 150 mm of the pile after stripping projects into the pile cap. A layer of surface reinforcement may be provided with a cover of 25 mm to retain the integrity of concrete below the main cap reinforcement which is to be laid 25 mm above the pile top. In marine conditions, or in areas exposed to the action of harmful chemicals etc., apart from the use of densely compacted concrete of a higher grade, the pile cap and the piles up to about 600 mm below low water or tide level should be protected with a suitable anti-corrosive paint. High alumina cement i.e. quick setting cement shall not be used in marine construction.

(6) **Grade of concrete in concrete piles**

For both precast and cast-in-situ piles, the values regarding grade of concrete, water cement ratio, slump shall be as follows;

Particulars	Tremie Concrete cast-in-situ	Driven cast-in-situ	Precast Concrete
Grade of concrete	M35	M35	M35
Min. cement content	400 Kg/m^3	400 Kg/m^3	400 Kg/m^3 *
Max. W.C. ratio	0.4	0.4	0.4
Slump(mm)	150-200	100-130	150

(7) **Driven precast concrete piles**

(I) Longitudinal reinforcement

The area of longitudinal reinforcement shall be based on the actual design but shall not be less than the following percentages of the cross sectional area of the piles:

(i) for piles with a length of less than 30 times the least width – 1.25 per cent.

(ii) for piles with a length of 30 to 40 times the least width – 1.5 per cent.

(iii) for piles with a length greater than 40 times the least width – 2 per cent.
The curtailment of the reinforcement along with the depth of pile shall avoid sudden discontinuity which may cause cracks during heavy driving.

(II) Lateral reinforcement

The lateral reinforcement is of particular value in restraining driving stresses and should be in the form of hoops, spirals or closed links. The minimum diameter of bars for this purpose shall not be less than 6 mm. The value of lateral reinforcement in the pile from each end for a distance of about 3 times the least width or diameter, shall not be less than 0.6 per cent of the gross volume and in the body of the pile not less than 0.2 per cent of the gross volume.

(8) **Driven cast-in-situ concrete piles**

(i) Reinforcement in the pile shall be provided in the entire length and shall be based on design. However, longitudinal reinforcement within the pile shaft shall not be less than 0.4 per cent of the gross sectional area in any part of the pile. (No reduction in steel area shall be permitted even if HYSD bars are used).

(ii) Where the casting pipe is withdrawn from cohesive soils for the formation of cast-in-situ piles, the concreting should be done with necessary precaution to minimise the softening of the soil by excess water. Cast-in-situ piles shall not be allowed where mud flow conditions exist.

(9) **Bored cast-in-situ piles**

(i) Reinforcement in the pile shall be provided in the entire length depending upon the manner of transmission of

the load by the pile to the soil and be not less than that specified above for driven cast-in-situ concrete piles.

(ii) In soils which are stable it may often be possible to drill an unlined hole and place the concrete without having a casting. In such cases, even if M20 concrete is used, the permissible stresses shall be limited to 80 per cent of the design value. In cases in which side soil can fall into the hole, it is necessary to stabilize the side of the bore hole with drilling mud or where possible a suitable steel lining may be used. The liner may be withdrawn when the concrete is poured inside or it may be left in position permanently especially in cases where the aggressive action of the ground water is to be avoided or in the case of piles built in marine condition.

(III) Precautions for concreting under water

(i) The concreting of the pile must be completed in one continuous operation.

(ii) The concrete should be coherent, rich in cement (not less than 400 kg/m^3) and of slump not less than 150mm. Minimum cement content shall be arrived at by increasing the cement content for dry condition under similar exposure condition and by 10 per cent. However, cement content should not be less than 400 kg/m^3.

(iii) When concreting is being carried out under water, a temporary casing should be installed to the full depth of soil except the portion in rock so that fragments of ground cannot drop from the sides of the hole into the concrete as it is placed.

(iv) The hopper and tremie pipe will have to be a closed system embedded in the placed concrete. through which water cannot pass.

(v) The tremie pipe will have to be large enough with due regard to the size of aggregate. For 20 mm aggregate; the tremie pipe should be of

diameter not less than 150 mm, and for larger aggregate larger diameter tremie pipes are required.

(vi) The first charge of concrete; should be placed with a sliding plug pushed down the tube ahead of it to prevent mixing of concrete and water.

(vii) The tremie pipe should always penetrate well into the concrete with an adequate margin of safety against accidental withdrawal if the pipe is surged to discharge the concrete.

(viii) The pile should be concreted wholly by tremie and the method of deposition should not be changed partway of the pile to prevent the laitance from being entrapped within the pile.

(ix) All tremie tubes should be scrupulously cleaned after use.

(x) The top of concrete in a pile shall be brought above the cut off level to permit removal of all laitance and weak concrete before pile cap is laid. This will ensure good concrete at the cut off level.

(xi) Load test on piles.

Load test shall be carried out as per IS:2911 (Part IV).

2.2.11.4. **Substructure** : Substructure include those portions of a bridge which are above the foundation which include piers, abutments, abutments and pier caps, dirt walls, returns, wing wall etc. but excludes bearings and superstructure. It can be built of brick/ stone masonry, plain/reinforced/prestressed concrete, steel. Selection of a particular type of substructure depends upon the span and type of superstructure, the height of substructure, availability of construction material and construction equipments, period and time of construction and above all on overall economy. The shape of piers and abutments

in general, should be such as to cause minimum obstruction to flow of water.

Substructure shall be designed to withstand the loads and forces as specified in IRC:6, the worst combination of forces and factors of safety shall be as specified in IRC: 78. For allowable stresses and other design requirements relevant IRC Codes depending upon the type of construction material shall be followed. The following general considerations shall also be satisfied.

(i) On all exposed faces of concrete member a minimum reinforcement equivalent to 2.5 kg/m^2 shall be provided to withstand stresses due to temperature and shrinkage with the maximum spacing limited to 200mm.

(ii) The width of abutment and pier cap should be fixed on the basis of design and construction requirements. Further it shall be sufficient to accommodate not only the bearings but also an off-set of 150mm beyond the edges of the bearings and also facilitate inspection and repairs of bearings. The thickness of such caps shall not be less than 225mm upto a span of 25m and 300mm for longer spans.

(iii) Suitably designed cut and ease waters shall be provided in piers upto affluxed HFL or higher from consideration of waves, etc.

(iv) The design of abutment-piers if provided shall be such that it should be possible to convert them to the similar shape as piers in the active channel.

(v) Multi-column piers across rivers carrying floating trees or timber, shall be braced by means of diaphragm walls extending unto affluxed HFL and having thickness not less than 200mm.

(vi) In case of hollow circular concrete piers outer diameter should not be less than 2.75m for total height of the pier. Thickness of shell shall not be less than 300mm and with vertical reinforcement not less than 0.4 per

cent of the cross sectional area of piers. Plain concrete cellular piers shall not be permitted.

The lateral reinforcement of the walls of hollow R.C.C. pier shall not be less than 0.3 per cent of the sectional area of the wall of the pier. This lateral reinforcement shall be distributed on both faces, 60 per cent on the outer face and 40 per cent on the inner face.

(vii) Where supports are made with 2 or more piles or trestle columns spaced closer than 3 times the diameter/width of the piles or 2 metre whichever is less, across the direction of flow, the group shall be treated as a solid pier of the same overall width, and value of shape constant (K) taken as 1.25 for working out the intensity of water pressure according to relevant clauses of IRC:6.

(viii) Spill through type abutments where adopted shall be provided with adequately designed pitched protection in front with apron/toe wall such that the entire system is safe from considerations of slipping, undermining etc. Usually the pitching is provided in a minimum slope of 1-1/2 H:1V. The screen wall provided shall extend at least upto 500 mm depth into the fill.

(ix) The top of wing return walls shall be carried 100mm above the top of the slope of embankment to prevent any soil from being blown or washed away by rain.

(x) Length of cantilever returns where adopted, shall not be more than 4 metres.

(xi) All abutments shall be designed for a live load surcharge equivalent to 1.2m height of earthfill.

(xii) All wing walls/return walls provided for full height of approaches shall be designed to withstand a live load surcharge equivalent to 0.6 m height of earthfill.

(xiii) In the case of spill through type abutments, the active pressure calculated on the width of columns shall be increased by 100 per cent.

(xiv) Structures designed to retain earthfill shall be proportioned to withstand pressure calculated in accordance with any rational theory. Coulomb's theory shall be acceptable subject to the modification that the center of pressure exerted by the backfill is located at an elevation of 0.42 of the height of wall above the base. No structure shall however be designed to withstand a horizontal pressure less than that exerted by a fluid weighing 480 kg/m^3. This is in addition to the surcharge.

(xv) The fill behind abutments, wing walls, and return wall shall conform to specifications given in IRC:78.

(xvi) In skew bridges, where bearings are placed at right angles to the longitudinal axis of the bridge, the top width of the piers/abutment has to be more compared to right bridges in order to have a clear distance of 150 mm beyond the edge of the bearings.

(xvii) In the case of navigational streams, the effect of barge impact has to be considered in the design of piers as suitable fenders are to be provided around the piers.

(xviii) For skew bridges provided with returns parallel to the bridge axis; the length of the wings at the obtuse angled corners will have to be more than the other ones, to ensure that the quadrantial revetment does not protrude into the waterway.

(xix) It is desirable to lay the abutment caps and the dirt walls over abutments with the same concrete and in one operation, and make them monolithic by detailing the reinforcement properly, to avoid cracking at the junction of the two components.

(xx) Adequate working space between the bottom of the superstructure main girders and top of pier/abutment caps, may be provided to facilitate inspection/replacement of bearings at a later date.

(xxi) R.C.C. piers may be preferred.

2.2.11.5. **Bearings**

(i) Bearings are vital components of a bridge which while allowing of longitudinal and/or transverse rotations and/ or movements of the superstructure with respect to the substructure (thus relieving stresses due to expansion and contraction), effectively transfer loads and forces from superstructure to substructure. Adequate care shall be exercised in selecting the right type of bearings based on the guidelines given below:

(a) For solid/voided slab superstructure resting on unyielding supports, no bearings are generally provided if the span length is less than 10m. The top of piers/abutments caps are however rubbed smooth with carborandum stone.

(b) For girder and slab spans more than 10m length and resting on unyielding supports, neoprene bearings may be considered.

(c) For spans larger than 25m roller and rocker bearings or PTFE bearings could be considered.

(d) For very large spans and where multidirectional freedom of movement and rotation are to be allowed provision of pot bearings may be considered.

(ii) The design of metallic bearings and neoprene bearings shall be in conformity with IRC:83 Parts I & II respectively.

(iii) In case of roller-cum-rocker bearings only full circular rollers are to be provided.

(iv) In order to cater for any possible relative undue movement of bearings over the abutment resulting in girder ends jamming against the dirt wall preferably a larger gap may be provided between the girder end and the dirt wall.

(v) All bearings assemblies shall be installed in accordance with the instructions contained in the codes and

specifications and on the approved drawings. In particular the following important points shall not be lost sight of:

(a) All bearings shall be set truly level so as to have full and even seating. Thin mortar pads (not exceeding 12mm) may be used to meet this requirement.

(b) The bottoms of girders resting on the bearing shall be plane and truly horizontal.

(c) In case of rockers and roller bearings, necessary adjustment for temperature at the time of placement, shrinkage, creep and elastic shortening shall be made, such that the line of bearing is as central as possible on the bearing plates at the normal temperature taken in design.

(d) For elastomeric bearing pads, the concrete surface shall be level such that the variation is not more than 1.5mm from a straight edge placed in any direction across the area.

(e) For spans in grade, the bearings shall be placed horizontal by using sole plates or suitably designed R.C.C. pedestals.

(f) Bearings of different sizes must not be placed next to each other to support a span.

(g) Installation of multiple bearings one behind the other on a single line of support is not permitted.

(h) The bearings shall be so protected while concreting the deck in situ that there is no flow of mortar or any other extraneous matter into the bearing assembly and particularly on to the bearing surfaces. The protection shall be such that it can be dismantlled after the construction is over without disturbing the bearing assembly.

(i) Special attention should be given to the temporary fixtures to be provided for the bearings during the concreting of superstructure in order to ensure that they do not get displaced during the initial installation itself. The temporary fixtures should be removed as soon as the superstructure has attained its required strength.

(vi) Bearings provided at any end of superstructure shall be along a single line of support and of identical dimensions.

(vii) Ministry of Road Transport and Highways, Govt. of India carries out pre-qualification of the manufacturers of bearings from time to time. The pre-qualification is valid for a certain period. It is advisable to procure bearings from such manufacturers only.

2.2.11.6. **Superstructure**

(i) It is the superstructure of a bridge that directly supports the traffic and facilitates its smooth uninterrupted passage over natural/man made barriers like rivers, creeks, railways, roads etc. by transmitting the loads and forces coming over it to the foundation through the bearings and substructure.

(ii) The minimum functional requirement of superstructure are specified in IRC:5 and IRC:21. In case of box girder superstructure, the minimum clear height inside the box girders shall be 1.5 m to facilitate inspection.

(iii) Aesthetic aspects already specified in para 2.10.2 will be one of the major considerations while deciding on the type of superstructure of a bridge keeping in view the criteria mentioned therein.

(iv) Consistent with economy and local availability of the materials, labour and technology for a particular type of superstructure selection may have to be made out of the following material options:

(a) Masonry
(b) Reinforced cement concrete
(c) Prestressed concrete
(d) Steel or
(e) Composite construction which is a combination of the any of the above.

(v) **Reinforced cement concrete superstructure:** These are the most popular type of superstructure in the present day which may take the form of solid slab, voided slab, T-beam and slab, box girder, rigid frame, arch, balanced cantilever or bow-string girder.

(vi) **Prestressed concrete superstructure:** This may also take any of the above forms referred in the previous para

(vii) **Steel superstructure:** With increasing availability of quality steel at international prices in recent years the use of steel for superstructure is becoming an attractive option. The forms, these may take are steel beam, plate girder, box girder, steel truss, arch, cantilever suspension bridges and cable stayed bridges.

(viii) **Composite superstructure:** Any combination of above materials considering their distinct advantages for particular elements may be adopted. Most common types of composite construction are cast in situ or precast girder in prestressed concrete with R.C.C. deck or steel beam/plate girders with RCC deck or cable stayed bridges with RCC or PSC deck.

(ix) **Design:** Relevant IRC Codes which have to be complied in the design of superstructure are IRC:40, IRC:21, IRC:18, IRC:24, IRC:22 for Masonry, Reinforced Cement Concrete, Prestressed Concrete and Composite Superstructures respectively. Other codes applicable for all types of superstructures are IRC:5 and IRC:6. Other major guidelines also include IRC:85. In case IRC codes are silent about some design aspects, provisions, in the IS/International Codes may be followed.

(x) **Provision for future pre-stressing:** In case of prestressed concrete superstructure, provision for future prestressing to the extent of 20 per cent of total prestress force may be made. For this purpose, dummy cables may be laid in the structure which can be used for further prestressing if the need arises afterwards.

(xi) **Standard plans for highway bridges:** Ministry of Road Transport & Highways gives preference to item rate contracts except in case of special problems, very large projects involving novel design/construction methods, and have brought out various standard plans which include standard plans for (i) RCC Solid Slab Superstructure with and without footpaths for 3m to 10m spans with 12.00m overall width, (ii) T-Beam and Slab Superstrucutre of 12m to 24m spans of overall width 12.00 m, (iii) PSC Girder with RCC Deck Composite Superstructure for 30 m span with and without footpath, 35m span with footpaths and 40m span without footpaths and (iv) RCC Solid Slab Superstructures of 15, 22.5, 30 and 35° skew for span 4m to 10m with and without footpaths. These plans are published by M/O RT&H / IRC and are listed in *Appendix-6.*

2.2.11.7. **Expansion joints** : Expansion joints are provided at the end of deck and cater for movement of deck due to temperature, shrinkage, creep etc. Expansion joints make the deck joint leak proof, protect the edges of slab/girder and also allow smooth passage of loads from one span to other by bridging the gap. Depending upon the gap width to be bridged, there are various types of expansion joints in use at present as detailed below.

(a) **Buried joints :** Where the gap is 20mm or less, bituminous/asphaltic surfacing is laid over a 12mm thick 200mm wide steel plate resting freely over the top surface of deck concrete. To keep the plate in position 8mm dia 100 mm long nails spaced at 300mm c/c along the center line of the plate are welded to the bottom surface of the plate and protrude into the gap.

(b) **Filler joint:** This type of joint is suitable for fixed ends of simply supported spans with insignificant movements or simply supported spans not exceeding 10 meters. It can cater for horizontal movement upto 20mm.

(c) **Asphaltic plug joint:** It is of asphaltic concrete made from polymer modified bitumen binder and selected

single size aggregate. It rests over a 6mm thick and 200mm wide steel plate placed over the gap. The width of the plug varies from 500 to 750mm and its depth varies from 75 to 100mm. It caters for a horizontal movement upto 25mm and vertical movement upto 2mm.

(d) **Compression seal joint:** It consists of steel armoured nosing at two edges of the joint gap suitably anchored to the deck concrete and a joint sealer performed multiweb cellular section of chloroprene elastomer compressed and fixed into the joint gap with special adhesive binder. The seal shall cater for a horizontal movement upto 40mm and vertical movement of 3mm.

(e) **Elastomeric slab seal joint:** It comprises of reinforced elastomeric seal fixed on either side to deck concrete of adjacent spans through bolts. It can cater to a maximum horizontal movement of 40mm.

(f) **Strip seal expansion joint:** It comprises of an extruded section of chloroprene held in position by edge beams made of either expanded or hot rolled steel section or cold rolled cellular steel sections with suitable profile to mechanically lock the sealing element. The edge beams are anchored to deck by reinforcing bars, headed studs or bolts or anchor plates. The working movement range of the sealing element shall be 70mm.

(g) **Modular Strip Seal/Box Seal Joint:** A modular expansion joint consists of two or more modules so as to cater to a horizontal movement in excess of 70mm. It allows movement in all the three directions and rotation about all the three axes as per design requirement. During all movement cycles of the joint, opening or closing of all modules are equal.

(h) **Special Joints:** For bridges having wide deck or span length of more than 120m or/and involving complex movements/rotations in different directions/planes provision of special type of modular expansion joints such as swivel joints may be made.

(i) Ministry of Road Transport & Highways, Govt. of India vide their letters No.RW/NH-34059/1/96 S&R dated 31.3.97 and 17.7.97 have issued interim specifications for expansion joints and subsequent modifications in the list of manufacturers / suppliers which may be followed. Supply of new type of expansion joints may be obtained on the basis of competitive bidding from amongst the manufacturers/suppliers listed at Annexure-II to the above referred letter. Further, a warranty of 10 years of trouble free performance may be insisted upon from the contractors/suppliers for all type of joints except for burried joints and filler joints.

2.2.12. **Corrosion protection measures**: Reinforced concrete has generally been considered to be a durable construction material. However, of late distress has been observed in several bridges primarily due to corrosion of embedded reinforcement. The cause of occurrence of corrosion is observed due to (1) hot and aggressive environment, (2) defective workmanship and (3) presence of chloride both in ingredients and/or atmosphere.

It is generally agreed that corrosion does not occur when adequate cover is provided on rebars, aided by well compacted concrete, since both water and oxygen are required in free state to initiate corrosion which will not occur in dry concrete or totally submerged condition. It is, therefore, imperative to use design mix concrete as cited in the Ministry's specification and strict quality control may be observed especially in severe marine conditions. Many approaches are available to inhibit or delay the onset of corrosion in rebars such as (i) usage of inhibitors in concrete, (ii) application of surface sealant (on concrete), (iii) metallurgical improvements in steel, (iv) cathodic protection, and (v) protective coatings on reinforcement. Ministry has brought out a circular vide No. RW/NH-34041/44/91-S&R dated 21.3.2000 giving detailed guidelines on use of fusion bonded epoxy coated reinforcement and other coatings for bridges on National Highways and other centrally sponsored bridges to be constructed in marine environment susceptible to severe corrosion which may be followed to reduce the chances of corrosion.

2.2.13. **Design of river training and protective works**

2.2.13.1. River training and protective works are required for ensuring the safety of bridges and their approaches on either side. The selection of the type of river training or protective work will depend upon terrain, overall behaviour of the river, location of the bridge vis-à-vis the areas of attack of the river, span arrangement, nearness of the approaches from the influence zone of the river, etc. The types of river training and protective works generally being used are as follows:

(i) Guide bunds
(ii) Spurs or groynes
(iii) River bank protection
(iv) Approach road protection
(v) River bed protection

The special features alongwith the broad design principles for each type are described in IRC:89–1987. "The Guidelines for Design and Construction of River Training and Protective Works for Road Bridges", which may be referred to for details.

2.2.14. **Preliminary cost estimate**

2.2.14.1. Preliminary cost estimate shall be a reasonably firm cost estimate on the basis of which administrative approval can be accorded. It shall be based on quantities worked out during preliminary design and current schedule of rates from which no major changes either in quantities or in rates shall normally occur except under totally unforeseen circumstances.

2.2.14.2. While preparing detailed project estimate, following additional points should also be kept in view:

(i) Structural elements like light posts and cable ducts for electrification of new bridges of lengths 300 m or more on National Highways may be provided, if required, and the cost thereof included in the estimate for the bridge proper provided that the Municipal Board/ concerned local authority is prepared to meet the initial

cost as well as subsequent maintenance charges of electrical installations including cost of wiring, lamps etc. and also to bear the electricity charges. Accordingly, the estimate should be accompanied by a clear certificate from the local authority who is prepared to meet the cost of electric installations and maintenance charges.

(ii) All proposals for reconstruction of existing weak bridges in National Highways should be accompanied with the rating of the bridges based on detailed provisions contained in IRC Special Publication No. 9 "Report on rating of bridges" for proper appreciation. Further, the inspection of existing structure should be done for collection of data in accordance with the provisions contained in Chapter R-3 of the aforesaid publication and the required information furnished.

(iii) It has been observed that the execution of several bridges across irrigation canals and distributaries get delayed due to the restrictions in working periods because of the perennial flowing in such canals. In the case of some such bridges, the Irrigation Authority have had to be specially approached for getting closure in the canals for the execution of bridges. Such special closures affect the normal irrigation activity and therefore, are not only easily not possible but also are not desirable in the overall national interest. In order to obviate such difficulties and to ensure completion of such bridges as per the pre-determined schedules, the guidelines as mentioned in *Appendix–7* may be followed in their planning and execution.

(iv) Road over/under bridges are constructed by the railway authorities on National Highways and other State roads (either as full deposit works or where the cost is to be shared between the Railway and Road authority). A simplified procedure for preparation of the detailed estimate and accord of technical approval has been evolved by the Ministry in consultation with the Ministry of Railways and the same is indicated in *Appendix–8.*

2.3. Detailed Project Preparation

2.3.1. **Survey :** Detailed Survey of the area, final selection of site, type of structure, type of foundations, span arrangement and alignment of approaches would have been completed at Preliminary Project Report stage. A further topographic survey may be required along the final alignment to verify the chainages, levels etc. and to fill in the gaps in the survey carried out during the Preliminary Project Report stage.

2.3.2. **Hydraulic designs :** Hydraulic designs done at the preliminary project report stage may be considered adequate unless special circumstances warrant updation of the same.

2.3.3. Detailed subsurface investigation and testing

2.3.3.1. All subsurface data necessary for detailed design of all the foundations separately, if necessary, have to be obtained during detailed subsurface investigations to be caried out in accordance with relevant IRC codal provisions and MOST's specifications..

2.3.3.2. For minor bridges atleast one bore at each of the abutment locations and one in the bed of the stream shall be taken.

2.3.3.3. In case of major bridges at least one bore shall be taken at each of the foundation locations.

2.3.3.4. The depth of subsurface exploration shall be based on the anticipated foundation level as per the Preliminary Project Report or from the details of foundations of existing bridges nearby, type of structure, span arrangements etc. and the bores shall extend at least 1-1/2 times the width of foundation for open and well foundation. In case of pile foundation, reference may be made to para 2.4.3.3.

2.3.3.5. For the portion of the approaches having embankment heights of 6.00m or more bore holes may be taken in the approach alignment to obtain data for the design of embankment as per IRC:75 "Guidelines for the Design of High Embankments".

2.3.3.6. Disturbed/undisturbed soil samples shall be taken at every 1.5m intervals. Also SPT or static penetration tests shall be

conducted at these intervals. Efforts shall be made to obtain undisturbed samples at least at alternate levels except in purely cohesionless soils. Data that are expected to be collected by the sampling and testing are: Soil classification, Particle size distribution, Shear strength characteristics, Permeability where dewatering is expected, Compressibility, Density, Void ratio, Moisture content, Nature and type of rock where met with and bearing capacity.

2.3.2.7. Subsoil investigations shall also determine the depth of watertable, artesian conditions, if any, and the quality of ground water.

2.3.4. **Detailed structural design**

2.3.4.1. Preferably detailed design should be done top downwards, i.e. superstructure to be finalised first, bearings next and so on, though it is started from foundation onwards in design and build contracts. Detailed structural design of all the components of the bridge have to be prepared at this stage with actual design parameters.

2.3.4.2. **Superstrcture**

(a) Detailed design and detailing of each of the elements of the superstructure have to be done during this phase.

(b) In case computer programmes are used for the analysis and/or detailing, it has to be ensured that the programme has been adequately validated. Also listing of input data and input values needs to be thoroughly checked and indicated for verification by approving authority.

2.3.4.3. **Bearings**

2.3.4.3.1. Detailed design of bearings shall conform to IRC: 83 Parts I & II for metallic and neoprene bearings and in case of special type of bearings like pot/PTFE bearings, specialised literature and codes and Ministry's Specifications for Roads & Bridge Works Section 2000 – clause 2006 may be referred and complied with.

2.3.4.4. **Substructures :** Unlike the typical design in preliminary stage, while preparing detailed design all individual

piers, abutments, returnwalls etc. which have any difference with regard to the forces acting, height of substructure etc. have to be separately analysed and designed individually if economy/safety demands so.

2.3.4.5. **Foundation :** In the case of foundations also each individual foundation has to be designed separately during the detailed design stage taking into account the difference in founding levels and the subsoil data as obtained at each of the individual foundation locations during detailed subsurface investigations.

2.3.4.6. **Secondary elements :** Detailed design of secondary elements like railings/crash barriers, expansion joints, kerbs, footpaths, approach slab etc. have also to be included in the D.P.R.

2.3.5. Detailed estimate

2.3.5.1. Detailed Estimate shall be based on finalised bill of quantities and current schedule of rates. The cost estimate so worked out have to be firm unless under unforeseen circumstances. The items of the estimate may be arranged systematically in the following order.

(i) Preparatory works
(ii) Foundations
(iii) Substructure
(iv) Superstructure
(v) Protective works
(vi) Miscellaneous items
(vii) Sub-estimate for approaches
(viii) Centage charges like quality control contingencies work charged establishment and agency charges.

2.3.5.2. The bill of quantities have to be based on detailed quantity estimates which again have to be based on detailed design and dimensions so arrived at for all the elements of the bridge.

2.3.5.3. The rates adopted shall be the current schedule of rates applicable for the region and wherever same items are not covered by the schedule, the rate for the same shall be based on detailed analysis of rates.

2.3.5.4. The agency and other charges applicable for estimates of National Highway Works are indicated under Cl.3.2.

2.3.5.5. The abstract of cost estimate containing the complete nomenclature of each item of works, final quantities as worked out in the detailed estimate, rates as in para 2.3.5.3 cost of each item and remarks, if any, shall invariably form part of the detailed estimate.

2.3.6. **Detailed project report :** Detailed Project Report should contain the following five volumes namely:

(i) Final Report
(ii) Detailed Designs
(iii) Detailed Estimate
(iv) Detailed Bill of Quantities and Specifications
(v) Detailed Drawings.

2.3.6.1. **Final report :** The final Report should contain:

(i) an introductory report indicating the location of the bridge, the need for the same, the population and economic activities likely to be served by the bridge, alternative sites considered and the aspects in favour of the site finally selected.

(ii) design data for the bridge including survey data, hydrdaulic data and subsoil data.

(iii) Detailed information on the general arrangement selected for the bridge and the factors favouring the choice.

(iv) Economic analysis of various options including the do nothing option in case of very major projects and atleast of the finally selected option in case of other projects.

(v) Report on the environmental impact assessment, and

(vi) A schedule of construction including a CPM chart in case of major projects; and atleast a Bar chart indicating important mile stones in other cases.

2.3.6.2. **Detailed designs :** Detailed design sheets of all components of the bridge have to be included in this volume.

2.3.6.3. **Detailed estimate :** This volume should contain all the items covered under para 2.3.5.

2.3.6.4. **Detailed bill of quantities and specifications :** The detailed bill of quantities should contain the :

(i) reasonably firm quantities of each item of work forming part of the project worked out on the basis of detailed drawings.

(ii) the detailed specifications of each of the items of the project.

2.3.6.5. **Detailed drawings :** This volume should contain the following:

(i) index plan

(ii) site plan

(iii) atleast three cross sections of the river as specified in para 2.2.4.2(ix)

(iv) a longitudinal section connecting the cross section points.

(v) A contour survey plan

(vi) Bore log data

(vii) A general arrangement drawing of the bridge superimposed on the cross section of the river at the proposed site also indicating the bore details

(viii) Detailed drawings of all the components of the bridge

(ix) Complete details of existing bridges, if any

(x) Plan and L section of approaches

(xi) Cross section of approaches

(xii) Detailed drawings of C.D. works

(xiii) Miscellaneous drawings.

3. TECHNICAL APPROVAL AND FINANCIAL SANCTION (ORIGINAL ESTIMATES)

3. TECHNICAL APPROVAL AND FINANCIAL SANCTION (ORIGINAL ESTIMATES)

3.1. General

Administrative/technical approval and financial sanction of original works on National Highways shall be accorded by the Central Government in accordance with prevailing National Highways rules made by Central Government on exercise of powers conferred by Section 9 of National Highway Act 1956 (48 of 1956).

3.1.1. Where the estimated cost of any original work on a National Highway, exceeds Rs 50 lakhs, a detailed estimate of the cost of the execution of the work shall be forwarded by the executive agency to the Central Govt. for obtaining technical approval and financial sanction.

3.1.2. Where the estimated cost of any original work on a National Highway does not exceed Rs 50 lakhs, the executing agency shall prepare a detailed estimate but forward only the general abstract of cost along with detailed information to the Central Govt. for accord of Administrative Approval. The executing agency shall accord technical approval and financial sanction to the detailed estimate already prepared within three months from the date of according administrative approval by the Central Government and shall commence execution of the work within one year from the date of according administrative approval failing which the Administrative Approval accorded by the Central Government shall stand cancelled automatically and the executing agency shall approach the Central Government for fresh administrative approval for the said work.

Copies of sanctions accorded by the executive agency should invariably be endorsed to the Regional officers concerned of the Ministry in the Central Government dealing with National Highways alongwith complete copy of the estimate so that ever after sanction, they could examine the matter and bring to the notice of the executive agency deviations from Ministry's specifications, instructions, guidelines, standard bridge designs if any.

3.1.3. No original work on any National Highway should be

undertaken by the executive agency until technical approval and financial sanction to the estimate for execution of the work has been accorded by the Central Govt. or the executive agency as the case may be except in case of emergencies such as flood or earthquake in which case it should be immediately reported to the authority competent to sanction the estimate and the audit officer concerned indicating the approximate amount of liability involved.

3.1.4. For works in para 3.1.1 above, the proposals shall be sent to the Central Govt. in two stages:

(i) A Technical appraisal note indicating the proposal.

(ii) A detailed project estimate on the basis of technical proposal as approved by the Central Government.

3.1.5. The Technical proposal or the Preliminary Project Report (PPR) and the detailed estimate also called Detailed Project Report (DPR) shall be prepared in accordance with Chapter 2 of this pocketbook.

3.1.6. The report prefacing the detailed estimate in the D.P.R. shall indicate the following:

(i) Proposal in brief

(ii) Plan provision

(iii) Extent of survey and investigations done

(iv) Traffic data

(v) Duration of execution

(vi) Phasing of expenditure and physical performance

(vii) Quantities and estimated cost under the following broad headings :

(a) Foundations
(b) Substructure including bearings
(c) Superstructure
(d) Guide bunds; if any

(e) Miscellaneous items
(f) Sub-estimate for approaches
(g) Contingencies
(h) Departmental charges.

(viii) Rates : Whether based on current schedule of rates in force or analysed rates. Ministry of Road Transport and Highways Standard Data Book shall be adopted for analysis of rates for NHs and Centrally sponsored works.

(ix) Cost benefit analysis

(x) Particulars for comparison of cost with those of similar works carried out in the region.

(xi) A certificate that land for the project has been acquired.

3.2. **Agency and Other Charges**

These charges are to be added as per following schedule/ sequence:

(i) Cost of work

(ii) Contingency charges @ 3% of (i) above.

(iii) Quality control charges @ 1% of cost of items permissible for the purpose.

(iv) Work charged establishment charges on (i) + (ii) above only, at the following rates :

(a)	Projects costing under Rs 25 lakhs	2%
(b)	Projects of Rs. 25 lakhs but below Rs. 50 lakhs.	1½%
(c)	Projects of Rs. 50 lakhs and above	1%

(v) Agency charges @ 9% of (i) + (ii) above.

There shall be no cumulative adding of centage charges.

Notes:

(1) In case of ROBs/RUBs where the job is to be carried out by Railway as deposit work and for which departmental charges are paid to them, the State PWDs are not entitled to Agency charges.

(2) Where the work is supervised by a consultant, agency charges shall be limited to 3 per cent only.

(vi) General Abstract of cost should be prepared as per *Appendix-9.*

3.3. Estimate for Survey Investigation on Project Preparation

For carrying out survey investigation and project preparation for major projects, the cost estimate may be prepared based on the schedule of rate in operation or based on terms of reference and bids received from the empanelled consultants and furnished to the Ministry for necessary sanction. List of empanelled consultants is issued from time to time by the Ministry and circulated to all concerned.

For small works like minor bridges etc., work may be carried out by the concerned agency i.e PWD through their regular staff, the expenditure on which is covered by the agency charges. Otherwise, the expenditure on survey investigation may be met out from their own resources which may be adjusted after the project is technically approved and financial sanction is issued by the Ministry.

3.4. Financial Powers

The delegation of financial powers to Ministry of Road Transport and Highways for NH Projects is as follows according to Minsitry's Circular No. RW/NH-11029/1/97-DOI dt. 4/1/99.

3.4.1. Projects costing upto Rs 15 crores can be approved by Ministry of Road Transport and Highways in the normal course.

3.4.2. Projects costing more than Rs 15 crores but less than Rs. 200 crores shall be considered by EFC headed by the Secretary (RT&H).

3.4.3. Schemes involving expenditure exceeding Rs. 200 crores but upto Rs. 500 crores shall be considered by Expenditure Finance Committee chaired by Secretary, (Expenditure).

3.4.4. Schemes involving expenditure exceeding Rs. 500 crores shall be approved by the Cabinet after clearance from the PIB/ EFC.

3.4.5. Proformae for preparing Memorandum for Expenditure Finance Committee for Original and Revised Estimates are given in Ministry's Circular No. CD-11017/2/98-TFI dt 3/11/98 and subsequent circulars on the subject if any.

4. CALL OF TENDERS, APPROVAL AND AWARD OF WORK

4. CALL OF TENDERS, APPROVAL AND AWARD OF WORK

4.1. General

Tender for works can be invited and finalised by the Executive Agency (State Government concerned) only after the administrative/ technical approval and financial sanction for these works is accorded by the Government of India as the case may be.

Tenders may be invited only on item rate basis on departmental designs, duly approved by Ministry of Road Transport and Highways. In case of very major bridges only, lumpsum tenders may be called based on contractors alternative designs and only after prequalification of contractors.

Tenders should be examined by the State Chief Engineer and appropriate decisions taken in accordance with the codal rules laid down in the State regulating decisions, tenders may be disposed by him or the State Government as the case may be. When such plans and designs are sent to the Ministry, they should be accompanied by a certificate from the State Chief Engineer/State Government to the effect that acceptance of the deviations and/or revised designs proposed by the tenders and recommended by the State will not involve any excess over the sanctioned cost as a result of any condition included in the tender.

4.2. Tender Procedure

4.2.1. **Works costing upto Rs. 5 crores :** Open bids may be invited from all the eligible contractors as per prevalent system in the State PWD / executing agency.

In case the cost of recommended tender for a work is more than the sanctioned cost beyond the permissible limits, reference has to be made by the State Govt. concerned to the Govt. of India along with copies of tender papers, comparative statement, their recommendations and the revised cost estimate based on recommended tender.

In those cases where the tender cost is equal to or less than the sanctioned cost of the work, but there has been material deviation from the technically approved design and or specifications only the plans and designs with relevant details should be sent to the Ministry of Road Transport & Highways for revised technical approval.

In case where it is difficult to assess the items involved or their cost, tenders can be invited by the executing agency and estimate of cost prepared on the basis of the same for obtaining approval from Central Government.

4.2.2. **Works costing more than Rs. 5 crores :** Ministry of Road Transport and Highways has brought out a Standard Bidding Document (SBD) which has been circulated vide Ministry's letter No. RW/NH-24020/2/99-PIC dated 4.10.2000 and made applicable to all National Highway works costing more than Rs. 5 crores w.e.f. 1st November 2000.

The main features of the SBD are as follows:

4.2.2.1. SBD attempts to incorporate all essential features of a model document such as a fair and transparent set of procedures and contract conditions, acceptable methods of dispute resolution, incentives for early completion and damages for delays etc. The document has been made applicable, initially to works costing Rs. 5 crores and above.

4.2.2.2. The limits of pre-qualification specified by Ministry, which is Rs. 20 crore and above remains unchanged. Wherever post-qualification has to be done (i.e. for works costing between Rs. 5 and 20 crore), the qualification information required to be furnished by the bidder as per section 2 shall be one of the important conditions for checking responsiveness of the bidder. Wherever prequalification has to be done (i.e. for works costing more than Rs. 20 crores), separate pre-qualification document shall be issued at appropriate time in advance. In the intervening period, the basis for pre-qualification will be decided by the authority calling the bid in accordance with qualification information as per section 2 appropriately adjusted for cost of works.

4.2.2.3. **Two stage evaluation**

(i) Bidding has to be a two stage process, viz. technical bid and financial bids. These two bids have to be received simultaneously but in separate sealed envelopes. Financial bids of only those bidders will be opened, whose technical bids have been found substantially responsive to the bid conditions i.e. the bidder accepts the bid conditions without reservation or material deviation. **If a bid does not contain the right amount of bid security which is to be furnished with the technical bid, his entire bid will be summarily rejected.** It has often been observed that bidders omit some important information or give some information on wrong pretext or inadequate understanding of the bid conditions. Even though the process of a Pre-bid Meeting has been provided in the document, during which a bidder can seek and get clarification for their questions, it has been decided to give them a second opportunity to rectify their mistakes. This will be immediately after evaluation of their technical bid. The bidders will be asked to correct the rectifiable mistakes within seven days. Where such corrections have a financial bearing, the bidders will be permitted to submit a revised financial bid by a specified date before opening of financial bids.

(ii) Financial bids will remain sealed and in the safe custody of the authority inviting the bid until the scheduled time of opening of the bid. Arithmetical correction of the bid, their acceptance by the bidders, un-realistically low priced items in the bid and additional performance security are some of the important aspects which need to be considered in financial evaluation of the bids.

4.2.2.4 **Time schedule for bidding activities :** Strict time schedule will be followed for evaluation of bids and award of contracts Time for accomplishing various activities have been given in the *Appendix-10.* The entire process from the date of receipt of bid to award of contract shall be completed within 40 days.

4.3. Prequalification of Contractors

For major road/bridge works costing Rs 20 crores and above contractors should be prequalified. The Project cost for prequalification of tenders would exclude the agency charges.

Prequalification of contractors is also to be resorted to in case of a bridge work when the overall length is more than 200 metres.

Concurrently, with the submission of detailed estimate to the Ministry, the invitation of prequalification bids and evaluation thereof should be taken up by the PWD and completed by the time the detailed estimate is sanctioned by the Ministry in accordance with para 3.1.3 above.

Latest prequalification documents published by the IRC, which are priced publications may be adopted.

4.3.1. **Invitation of bids for prequalification** : The advertisement for prequalification should be issued at least in four national papers (two in Hindi and two in English), the Indian Trade Journal, the Indian Highways and two regional papers, one in Hindi and the other in the local language. In regions where there is no Hindi regional Newspaper the advertisment may be issued in two regional papers, one in English and other in the local language.

It may also be ensured that copies of the advertisements/NITs are suitably displayed in the offices of the authority inviting the bids for wide publicity.

Contractors from all over the country can apply for prequalification.

4.3.2. **Evaluation of prequalification bids** : After receipt of the pre-qualification bids, the scrutiny of the same will be carried out in the Ministry according to the guidelines contained in Ministry's Circular No. RW/NH/11024/1/94-DOI dated the 15th June, 1994.

4.3.3 Evaluation of tenders for externally aided National Highway Projects.

The evaluation of tenders will be done by a Committee consisting of officers of Roads Wing and Finance Wing of this Ministry and Chief Engineers (NH) of the concerned State PWDS (Ref. Ministry's Circular No. RW/NH-11024/3/94-DO-I dt. 17/10/94).

4.4. Powers of State Governments

Level at which Tenders should be invited and time of invitation.

The tenders are to be invited directly by the authority empowered to accept them.

The State Government may accept tenders, if the excess over sanctioned estimate does not go beyond the value determined on the basis of current schedule of rates by 15 per cent subject to the following conditions.

(i) For tender involving material deviation from approved designs and/or specifications for the work, the same shall be referred to the Government of India accompanied by plans, and detailed comments thereon by the State Governments/Chief Engineer.

(ii) These powers are to be exercised by the State Government themselves, who if they so desire may also delegate these powers to officers not below the rank of the Chief Engineer under intimation to this Ministry.

(iii) After the tenders have been accepted by the State Government, the revised estimates should be sent to the Government of India for their sanction within one month of the acceptance of the tenders, this time limit being extended upto 2 months in unavoidable cases. A copy of the approved current schedule of rates should accompany the revised estimates, invariably.

(iv) The tenders for externally aided National Highway Projects after their receipt by the State Governments will be forwarded immediately by them to the Ministry for evaluation and finalisation. The evaluation of the

tenders will be done by a Committee consisting of officers of Roads Wing and Finance Wing of the Ministry and Chief Engineer (NH) of the concerned State PWD. After evaluation, the tenders will be sent to the State Govt. for award of work and preparation of the revised estimate.

4.5. Contents of Tender Documents

VOLUME 1 :	Notice inviting tender Instructions to Tenders Conditions of Contract Qualification information and other forms
VOLUME 2 :	Contract data Technical Specifications
VOLUME 3 :	Form of Tender Bill of Quantities Securities and other forms Annexures
VOLUME 4 :	Drawings
VOLUME 5 :	Documents to be furnished by the bidder

5. PRIVATE PARTICIPATION FOR CONSTRUCTION OF BRIDGES IN THE DEVELOPMENT OF NATIONAL HIGHWAYS AND ROAD INFRASTRUCTURE UNDER BOT SCHEME

5. PRIVATE PARTICIPATION FOR CONSTRUCTION OF BRIDGES IN THE DEVELOPMENT OF NATIONAL HIGHWAYS AND ROAD INFRASTRUCTURE UNDER BOT SCHEME

5.1. Background

Industrialisation in the country has induced a traffic growth of 8 to 12 per cent per year on many sections of National Highways and this growth trend is expected to continue. While the traffic on the National Highways has been growing at a rapid pace, it has not been possible for the Government to provide matching funds due to competing demands from other priority sectors. This has led to large number of deficiencies in the network. Looking to the resources, GOI has made a policy decision to augment resources for development of road sections by inviting private participation.

To motivate the inflow of the resources for the development , maintenance and management of national highways and to improve their efficiency and to bring in competitiveness in providing private highway services to road users, the Government of India welcomes private investment in national highways. This would help in improvement of the existing highways and bring in the latest technology and improve management techniques.

5.2. BOT Policy

The functions relating to development, maintenance and management of national highways are carried out by the Central Government under the provision of National Highways Act 1956. This Act has been amended in June 1995 to permit private sector participation which inter-alia provides:-

(1) Central Government may enter into an agreement with any person in relation to development and maintenance of the whole or any part of the National Highway

(2) The person referred to above (i) is entitled to collect and retain the fees at such rates for services or benefits

rendered by him as the Central Government may by notification in the Official gazette specify having relation to the expenditure involved in building, maintenance, management and operation of the whole or part of a National Highway, except on capital investment, reasonable returns, volume of traffic and the period of such agreement. General guidelines for private investment in National Highway projects has been circulated by Government of India vide Ministry's letter No. RW/NH-24035/23/94-PL dated 21/1/97.

5.3. Salient Features of BOT Policy

5.3.1. Rules have been framed under the amended National Highways Act laying down the procedure for collection of fee by any person or Government on sections of national highways including permanent bridges developed by the entrepreneur or the Government respectively.

5.3.2. **Policy making body** : All policy matters relating to national highways are decided by the Ministry of Road Transport and Highways.

5.3.3. **Implementing Agencies**: Ministry of Road Transport and Highways has decided that the policy of privatization of the national highways will be implemented by the National Highways Authority of India and the State PWDs.

5.3.4. **Enterprise:** Enterprise will mean the successful bidder with whom the Government and the implementing agency have entered into agreement for developing, maintaining and operating a National Highway project.

5.4. Identification of Project for Private Investment

Following principles will be observed in identification of national highway projects for private investment:

(a) Project is one of the approved projects of the Ministry of Road Transport and Highways.

(b) Project is capable of yielding adequate economic rate of return and financial internal rate of return.

5.5. Data required for Inviting Bids for Private Participation

The Government will carryout all preparatory works as detailed below for the projects identified for private investment and meet the cost of following items:

(a) Detailed feasibility study
(b) Land for right of way and enroute facilities
(c) Clearance of the right of way land; relocation of utility services, cutting of trees, resettlement and rehabilitation of the affected establishments, removal of all encroachments.
(d) Environmental clearance
(e) In case of ROBs clearance from railways to allow private enterprise to build the ROB under railways' supervision and finalising of GAD and charges payable to railways.
(f) Where design is left to the enterprise, giving details of standards and bore-hole logs at bridge sites etc.
(g) Depending on the financial viability of the project, the Government may recoup its investment on the above items from the project.

5.6. Facilitating Measures/Concession Provided by the Government to motivate entrepreneur

Following concessions are being provided by the Government:-

(a) Import duty has been exempted on identified high quality construction plants and equipments
(b) In case of projects which are on the verge of financial viability, suitable traffic support/guarantees could be considered on case to case basis.
(c) Entrepreneur is entitled to a tax holiday on profits and gains derived from such business for the initial 5 Assessment Years and thereafter, 30 per cent of such profits and gains are exempt from corporate tax. This tax concession may be availed of by the entrepreneurs in any 10 consecutive assessment years falling within a

period of 20 assessment years from the commencement of operation and maintenance.

(d) Incentive to financial institutions to provide finance for the infrastructure projects has also been given.

(e) **Other concessions**: Way side amenities be made integral part of BOT highway projects to enhance the viability of the project on case to case basis. The profit from such activities would be treated as income from infrastructure projects for the purpose of tax exemption, provided these are ploughed back to the development of roads on BOT basis within a period of 3 years.

(f) **Foreign investment:** Government has decided to permit automatically foreign direct investment upto 100% equity for road and bridge construction as part of infrastructure development upto Rs. 1500 crores. External Commercial Borrowings (ECB) is permitted upto 35% of the project cost for rupee expenditure.

5.7. Concession period

Concession period comprises of:

(i) construction period which will be project specific

(ii) period during which the enterprise is permitted to levy fee and is liable for maintaining the facility which will be determined on competitive bidding basis. The total concession period can be upto a maximum of 30 years. The concession period may be extended suitably to cover any Force Majeure conditions.

5.8. Fee

The maximum fee rates leviable on completed 4 lane sections and approved by the Cabinet have already been circulated. However, different fee rates for other projects can be levied depending on the project cost and the traffic levels. The revision of the fee may be allowed every year following commissioning of the facility linked to the wholesale price index.

5.9. Stages in implementation of BOT Project

(i) Completion of preparatory works as detailed in para 5.5

(ii) Finalisation of bidding document

(iii) Invitation of bids

(iv) Pre-bid conference

(v) Evaluation of bids

(vi) Award of concession

(vii) Signing of the agreement

Bidding Document

The bidding document should include the model concession agreement format and leave very little for negotiation before signing of agreement. M/o RT&H has brought out 2 documents on Model Concession Agreement i.e. (i) for smaller projects costing upto Rs. 100 crore, and (ii) for projects costing over Rs. 100 crore. For BOT projects which may invariably be used.

5.9.1. **Invitation of bids :** A project will be classified into the following two categories:-

Category 1: ROBs, bypasses, bridges, tunnels and interchanges costing upto Rs. 100 crores as per the feasibility Study.

Category 2: All projects relating to 4 laning of expressways and projects relating to bridges each costing more than Rs. 100 crores.

5.9.2. **Evaluation of bids**

5.9.2.1. The technical bids for Category 1 and the proposal for short listing of bidders for Category 2 will be evaluated keeping in view inter-alia:

(i) Experience of the enterprise

(ii) Experience of the contractors or/consultants

(iii) Capacity of the enterprise to raise funds from the market

(iv) Financial strength of the enterprise

(v) Quality and adequacy of the organization, and institutional arrangements proposed for implementation

(vi) The technical bids in respect of Category 1 and the proposal for short listing of bidders for the Category 2 projects will be evaluated and finalized by a Committee of the Implementing Agency. Such evaluations will be based on the criteria indicated to the bidders while inviting their offers.

5.9.2.2. **Evaluation of financial bids:** This will be carried out on the principle of least cost to the user.

5.9.2.3. **Award of the concession of signing of agreement :** After evaluation of the bids and approval of the award by the Government, a letter of acceptance of the bid will be issued by the implementing agency in favour of successful bidder. The letter of acceptance will inter-alia specify the formalities to be completed by the successful bidder for signing of the agreement.

The draft of the concession agreement could be provided to the bidder prior to the bid which shall inter-alia include form of the agreement. Ministry of Road Transport and Highways has evolved model concession agreement/document, which should invariably be used for National Highway works. The concession agreement shall be signed by the successful bidder and the implementing agency and the Central Government.

5.9.2.4. **Construction of road over/under bridges on build, operate and transfer basis:** In case of construction of road over/ under bridges on BOT basis, approval of the railway authorities will also be required. Railway authorities have circulated a standard

agreement format vide their letter No. RW/NH-98/CE-1/Misc/14 (BRO) dated 13.12.98 which was circulated to all concerned agencies vide Ministry's letter No. RW/NH-15015/12/97-PL datd 16.2.99. While signing the concession agreement, the format circulated by railway authorities should be used.

5.10. **Regulatory Frame Work**

The implementing agency will carry out the regulatory functions. The upper limit of the user fee applicable for the initial year will be stipulated in the agreement together with the fee revision formula for the subsequent years and appropriate upper limit of the fee shall be notified by the Government from time to time. The enterprise will be free to charge less than the notified fee. The implementing agency will ensure that highway facility is available to all the users on equal terms and no user is charged more than the notified fee or harassed in any manner or subject to any unfair or restrictive practices. The implementing agency will also ensure that the highway stretch is maintained to the proper standards. The implementing agency may carryout surprise and periodic checks, and for any default to the enterprise, suitable penalties on the defaulting enterprise may be imposed by the implementing agency in accordance with the concession agreement. Cost of testing, quality assurance etc., is to be met by the entrepreneur and suitable programme for the same shall be made in this regard.

The enterprise will be obliged to protect the national interests like national security whenever necessary and required. They will abide by various statutory requirements relating to protection of environment, safety etc., and also abide by the directives issued by the Government/implementing agency in this regard from time to time, in accordance with the provisions of the Concession Agreement or the Laws in force.

5.11. **Transfer of the Project to the Government**

For the purposes of transfer, the project will consist of the assets built within the right-of-way and the junction/inter-section areas and the en route highway related facilities . At the end of the concession agreement, the project, in sound condition shall be

transferred by the enterprise to the Government free of any cost. The standards to which the project will conform to at the time of its transfer to the Government will be laid down in the concession agreement. Even after the transfer of the project to the Government, the implementing agency will continue to exercise control on the highway related developments at the entry/exit points and the advertisements.

5.12. **Dispute Resolution**

Day to day decisions on the implementation of the agreements will be made by the Steering group or independent Engineer, as the case may be. Any dispute between the Implementing Agency, the Government and the enterprise will be settled under the provisions of Indian Arbitration and Conciliation Act, 1996.

6. REVISED ESTIMATE

6. REVISED ESTIMATE

6.1. Necessity

6.1.1. Where the expenditure on any original work on a National Highway, sanctioned by Central Govt., is likely to exceed or exceeds the sanctioned amount by more than 15 per cent thereof or by a sum of Rs 1 crore, whichever is less, revised sanction is required to be obtained from Central Government.

6.1.2. Where the expenditure on any original work on a National Highway, Sanctioned by the executing agency, is likely to exceed or exceeds the sanctioned amount by more than 15 per cent thereof or Rs 50 lakhs, whichever is less, revised sanction is required to be obtained from Central Government.

6.1.3. Where the expenditure on any original work on a National Highway, sanctioned by the executing agency is likely to exceed or exceeds the sanctioned amount by more than 15 per cent thereof (but does not exceed by more than 15 per cent of the sanctioned amount and determined on the basis of current SOR approved by the Central Govt.) or Rs. 50 lakhs whichever is less, the executing agency can itself accord the revised technical approval and financial sanction provided the excess is solely due to routine factors, such as increase in cost of labour and materials and not due to revision in the scope of work already approved.

6.1.4. Revised Cost Estimate (RCE) is also required to be submitted to GOI if the revised cost is beyond the sanctioning powers of the authority approving the original estimate i.e. PWD (less than Rs. 50 lakhs), Ministry (Rs 50 lakhs and above but less than Rs. 15 crores), Standing Committee (Rs 15 crores and above but less than Rs 200 crores) irrespective of the percentage increase in cost.

6.1.5. No excess is permissible over revised sanctioned cost. In case of any excess over the revised sanctioned amount, a re-revised estimate shall be prepared and fresh approval to the same shall be obtained from Central Government.

6.1.6. In case the excess is purely on account of higher tender rates, the revised estimate based on recommended tender rates, along with tender papers shall be submitted to the Central Government for obtaining approval.

6.2. Submission of RE

6.2.1. Revised estimate for any work shall be submitted by the State PWD within one month of the date a revision of its cost is found necessary based on tender or within three moths of the date a revision is found necessary during the periodic critical review meeting being held in the Ministry.

6.2.2. Revised estimates should be submitted in complete shape alongwith all the essential documents to facilitate prompt scrutiny of the same in the Ministry and to avoid delay in correspondence for seeking various details /clarifications from time to time. The Ministry has already prescribed a check list for ensuring this, which is required to be appended to each revised estimate. A copy of the same is again enclosed for reference.

6.2.3. In case of requirement of clarifications on the RCEs, the same shall be done by the State PWD within one month of receipt of the Ministry's observations. However, in the event of requirement of resubmission of RCEs, the same shall be done in two months.

6.2.4. In case the revised estimates in complete shape along with the check list are not submitted within the specified time frame, as mentioned in para 2 above and if clarifications are not submitted within one month, the same will be considered for sanction only after deleting any agency charges on the additional cost beyond original/ earlier revised sanction. The State PWD themselves will be fully responsible for the consequent financial loss to the State Government.

6.3. Contents of the Revised Estimate

6.3.1. Background note giving detailed explanation for the revision in the rates, quantities and or scope of work for each item.

6.3.2. The upto-date physical and financial progress of the project along with a pictorial chart.

6.3.3. Ministry's letters approving the change of scope and/or specifications and rates.

6.3.4. Certified copy of contract agreement.

6.3.5. Compliance to technical note accompanying the sanction letter.

6.3.6. Original as well as revised proposal marked on drawings. Completion drawings where the work has already been executed.

6.3.7. Items and their quantities which have already been executed.

6.3.8. Whether the rates are based on tenders, schedule of rate, actuals or analysed ones.

6.3.9. Sub estimates for lump sum items.

6.3.10. Comparative statement of cost bringing out clearly the excesses/savings on various items alongwith reasons indicated against each. The format for comparative statement is given in *Appendix-11*.

6.3.11. Adjustment of salvage value of dismantled material.

6.3.12. For completed works the contingency and work charge items are to be provided as per actuals subject to ceilings prescribed.

6.3.13. Pending claims, if any.

6.3.14. Certificate of cent per cent check by a responsible officer.

6.3.15. Audit Para: Details of pending audit para should be furnished.

7. CONSTRUCTION

7. CONSTRUCTION

7.1. General

7.1.1. The execution of a bridge may be taken up departmentally or through a contracting agency. Before start of construction work care must be taken to ensure that the following documents are available:

(i) Sanction letter and technical note, if any.

(ii) Bill of quantities.

(iii) Copy of contract document along with any special conditions thereof.

(iv) Copy of approved set of plans and detailed working drawings.

(v) Standards, specifications, guidelines, codes of practices etc., according to which the work must be executed as per contract.

(vi) Survey, investigation and sub-soil test reports.

7.1.2. Finalise the site and decide location of site office, storage sheds, batching plant, casting yard, labour camp etc.

7.1.3. Identify sources of construction materials like sand, coarse aggregate and boulders etc. and supply of cement and steel including the time required in transportation of these materials to the site of work.

7.1.4. Draw a detailed work programme (CPM) on the basis of availability of plant, equipment, material, manpower etc. Refer IRC Special Publication No. 14 - A manual for application of the critical path method.

7.1.5. Identify major milestones to serve as important dates for reviewing the progress of work.

7.1.6. After having cleared the site, transfer the alignment of the bridge and ground with the help of reference pillars fixed at site during the location survey. Fix up permanent bench marks, guide/ reference pillars. Use Auto levels, accurate theodolite and other precision electronic instrument.

7.1.7. The construction of various components of bridge works and protective works shall conform to Ministry's Specification for Road and Bridge Works and relevant IRC Bridge Codes/Standards. However, some of the salient points are mentioned below:

7.2. Concrete

7.2.1. Grades of concrete

7.2.1.1. The grades of concrete are designated by the characteristic strength which is defined as the strength of concrete below which not more than 5 per cent of the test results are expected to fall.

7.2.1.2. The lowest grades of concrete in bridges and corresponding minimum cement contents and water-cement ratios to ensure durability of concrete are given hereunder.

Table 7.1 For bridges with prestressed concrete or those with length more than 60 m or more and those that are built with innovative design/construction.

A. Minimum Strength of Concrete

Sl.No.	Member	Conditions of exposure	
		Moderate	Severe
a)	PCC	M 25	M 30
b)	RCC	M 30	M 35
c)	PSC	M 35	M 40

B. Minimum Cement Content and Max. Water Cement Ratio

	Structural Member	Minimum cement content for all exposure conditions (kg./cu.m)	Max. water cement ratio	
			Exposure Conditions	
			Severe	Normal
a)	PCC Members	360	0.45	0.45
b)	RCC Members	400	0.45	0.40
c)	PSC Members	400	0.40	0.40

Table 7.2 For bridges other than those mentioned in Table 7.1 and for culverts and other incidental construction :

A. Minimum Strength of Concrete

	Member	Condition of Exposure	
		Moderate	Severe
a)	PCC members	M 15	M 20
b)	RCC members	M 20	M 25

B. Minimum Cement Content and Maximum Water Cement Ratio

Structural Member		Min. cement Content (kg/cu.m)		Max. water cement ratio	
		Exposure Condition		Exposure Condition	
		normal	severe	Normal	severe
a)	PCC members	250	310	0.50	0.45
b)	RCC members	310	360	0.45	0.40

(*Notes* applicable to Table 7.1 & 7.2)

(i) The minimum cement content is based on 20 mm aggregate (nominal max. size). For 40 mm and larger size aggregates, it may be reduced suitably but the reduction shall not be more than 10 per cent.

(ii) For underwater concreting, the cement content shall be increased by 10 per cent.

(iii) Severe conditions of exposure shall mean marine environment, alternate wetting and drying due to sea spray, alternate wetting and drying combined with freezing and buried in soil having corrosive effect, members in contact with water where the velocity of flow and the bed material are likely to cause erosion of concrete.

(iv) Moderate conditions of exposure shall mean other than those mentioned in (iii) above.

The cement content shall be as low as possible but not less the quantities specified above. In no case shall it exceed 540 kg/cu.m of concrete.

7.2.1.3. For all items of concrete,only "Design Mix" shall be used, except where "Nominal Mix" concrete is permitted.

7.2.2. **Proportioning of concrete**

7.2.2.1. Prior to start of the construction, the Contractor shall design the mix in case of "Design Mix Concrete" or propose nominal mix in case of "Nominal Mix Concrete", and submit to the Engineer for approval, the proportions of materials, including admixtures to be used.

7.2.2.2. Maximum slump shall be as specified below:

Type	**Slump (mm)**
(1)(a) Structures both with plain or reinforced concrete with exposed	

	inclined surface requiring low slump concrete to allow proper compaction	25
(b)	Plain cement concrete	25
(2)	RCC structure with widely spaced reinforcements; e.g. solid columns, piers, abutments, footings, well steining.	40 - 50
(3)	RCC structure with fair degree of congestion of reinforcement; e.g. pier and abutment caps, box culverts well curb, well cap, walls with thickness greater than 300 mm.	50 - 75
(4)	RCC and PSC structures with highly congested reinforcements e.g. deck slab, girders, box girders, walls with thickness less than 300 mm.	75 - 125
(5)	Underwater concreting through tremie e.g. bottom plug, cast-in-situ pilling.	100 - 200

7.2.2.3. **Requirements for design mixes**

(a) **Target mean strength**

The target mean strength of specimen shall exceed the specified characteristic compressive strength by at least the "current margin"

(i) The current margin for a concrete mix shall be determined by the Contractor and shall be taken as 1.64 times the standard deviation of sample test results taken from at least 40 separate batches of concrete of similar proportions produced by the same plant under similar supervision, over a period exceeding 5 days, but not exceeding 6 months.

(ii) Where there is insufficient data to satisfy the above, the

current margin for the initial design mix shall be taken as given in the Table 7.3.

Table 7.3. Current Margin from Initial Design Mix Concrete

Concrete Grade	Current Margin (Mpa)	Target Mean Strength (Mpa)
M 15	10	25
M 20	10	30
M 25	11	36
M 30	12	42
M 35	12	47
M 40	12	52
M 45	13	58
M 50	13	63
M 55	14	69
M 60	14	74

The initial current margin given in the table above shall be used till sufficient data is available to determine the current margin as per sub-clause-(i) above. Higher grade of concrete can be considered using silica fume after the same is tested and recommended after research study.

Any recognized method may be used for mix design. A set of specimen forms that may be used for finalizing the data for the field are given in *Appendix–12*.

(b) **Trial mixes**

Test cubes shall be taken from trial mixes as follows. For each mix, set of six cubes shall be made from each of three consecutive batches. Three cubes from each set of six shall be tested at an age of 28 days and three at an earlier age approved by the Engineer. The cubes shall be made, cured, stored, transported and tested in conformity with Ministry's Specifications. The average strength of the nine cubes at 28 days shall exceed the specified characteristic strength by the current margin minus 3.5 MPa.

(c) Requirements of nominal mix concrete

Requirement for nominal mix concrete unless otherwise specified, shall be as detailed in Table 7.4 given below.

Table 7.4. Proportions for nominal mix concrete

Concrete Grade	Total Quantity of dry aggregate by mass per 50 kg of cement to be taken as the sum of individual masses of fine and coarse aggregates (kg)	Proportion of fine to Coarse aggregate (by mass)
M 15	350	Generally 1:2, subject to upper limit 1: 1.5 and lower limit of 1:2:5
M 20	250	- do -

7.2.2.4. **Additional requirements :** Concrete shall meet with any other requirements as specified on the drawing or as directed by the Engineer. Additional requirements shall also consist of the following overall limits of deleterious substances in concrete.

(a) The total chloride content of all constituent as a percentage of mass of cement in mix shall be limited to values given below:

Prestressed Concrete	0.1 per cent
Reinforced concrete exposed to chlorides in service (e.g. structures located near sea coast)	0.2 per cent
Other reinforced concrete construction.	0.3 per cent

(b) The total sulphuric anhydride (SO_3) content of all the constituents of concrete as a percentage of mass of cement in the mix shall be limited to 4 per cent.

7..2.2.5. **Suitability of proposed mix proportions :** The Contractor shall submit the following information for the Engineer's approval:

(a) Name and source of each material

(b) Quantities of each material per cubic metre of fully compacted concrete.

(c) Either of the following :

(i) appropriate existing data as evidence of satisfactory previous performance for the target mean strength, current margin, consistency and water/cement ratio and any other additional requirement(s) as specified.

(ii) full details of tests on trial mixes.

(d) Statement giving the proposed mix proportion for nominal mix concrete.

Any change in the source of material or in the mix proportions shall be subject to the Engineer's prior approval.

7.2.3. **Admixtures :** Admixtures for concrete shall be used with the approval of the Engineer.

As the selection of an appropriate concrete admixture is an integral part of the mix design the manufacturer shall recommend the use of any one of his products only after obtaining complete knowledge of all the actual constituents of concrete as well as methodologies of manufacture, transportation and compaction of concrete proposed to be used in the project.

7.2.4. **Size of coarse aggregate**

7.2.4.1. The size (maximum nominal) of coarse aggregates for concrete to be used in various components shall be as given in the Table below:

Table 7.5

Sl. No.	Components	Maximum Nominal Size of Coarse Aggregate (mm)
(i)	RCC well curb	20
(ii)	RCC/PCC well steining	40
(iii)	Well cap or Pile Cap Solid Type piers and abutments	40
(iv)	RCC work in girders, slabs, wearing coat, curb approach slab hollow piers and abutments, pier/abutment caps, piers.	20
(v)	PSC work	20
vi)	Any other item	As specified by Engineer.

7.2.4.2. Maximum nominal size of aggregates shall also be restricted to the smaller of the following values:

(a) 10mm less than the minimum lateral clear distance between main reinforcement.
(b) 10mm less than the minimum clear cover to the reinforcement.

7.2.4.3. The proportions of the various individual size of

aggregates shall be so adjusted that the grading produces densest mix and the grading curve corresponds to the maximum nominal size adopted for the concrete mix.

7.2.5. **Equipment :** Unless specified otherwise, equipment for production, transportation and compaction of concrete shall be as under:

(a) **For production of concrete**

(i) For overall bridge length of less than 200 metres – batch type concrete mixer diesel or electric operated, with a minimum size of 200 litres, automatic water measuring system and integral weigher (hydraulic/pneumatic type).

(ii) For overall bridge length of 200 metre or more – concrete batching and mixing plant fully automatic with minimum capacity of 15 cu.m. per hour.

All measuring devices of the equipment shall be maintained in a clean and serviceable condition. Its accuracy shall be checked over the range in use, when set up at each site and thereafter periodically as directed by the Engineer.

(b) **For concrete transportation**

(i) Concrete dumpers
(ii) Power hoists
(iii) Chutes
(iv) Buckets handled by cranes
(v) Transit truck mixer
(vi) Concrete pump
(vii) Concrete distributor booms
(viii) Belt conveyor
(ix) Cranes with skips
(x) Tremies

(c) **For compaction of concrete**

(i) Internal vibrators

(ii) Form vibrators
(iii) Screed vibrators

7.2.6. **Mixing concrete**

7.2.6.1. Concrete shall be mixed either in a concrete mixer or in a batching and mixing plant. Hand mixing shall not be permitted.

7.2.6.2. Mixing shall be continued till materials are uniformly distributed and a uniform colour of the entire mass is obtained, and each individual particle of the coarse aggregate shows complete coating of mortar containing its proportionate amount of cement. In no case shall mixing be done for less than 2 minutes.

7.2.6.3. Mixers which have been out of use for more than 30 minutes shall be thoroughly cleaned before putting in a new batch. Unless otherwise agreed to by the Engineer, the first batch of concrete from the mixer shall contain only two thirds of the normal quantity of coarse aggregate. Mixing plant shall be thoroughly cleaned before changing from one type of cement to another.

7.2.7. **Transporting, placing and compaction of concrete :** The method of transporting and placing concrete shall be approved by the Engineer. Concrete shall be transported and placed as near as practicable to its final position, so that no contamination, segregation or loss of its constituent materials takes place. Concrete shall not be freely dropped into place from a height exceeding 1.5 metres.

When concrete is conveyed by chute, the plant shall be of such size and design as to ensure practically continuous flow. Slope of the chute shall be so adjusted that the concrete flows without the use of excessive quantity of water and without any segregation of its ingredients. The delivery end of the chute shall be as close as possible to the point of deposit. The chute shall be thoroughly flushed with water before and after each working period and the water used for this purpose shall be discharged outside the formwork.

All formwork and reinforcement contained in it shall be cleaned and made free from standing water, dust, snow or ice immediately before placing of concrete.

Fresh concrete shall not be placed against concrete which has been in position for more than 30 minutes unless a proper construction joint is formed.

Except where otherwise agreed to by the Engineer, concrete shall be deposited in horizontal layers to a compacted depth of not more than 450 mm when internal vibrators are used and not exceeding 300mm in all other cases.

Concrete when deposited shall have a temperature of not less than 5 degrees Celsius, and not more than 40 degrees Celsius. It shall be compacted in its final position within 30 minutes of its discharge from the mixer, unless carried in properly designed agitators, operating continuously, when this time shall be within 1 hour of the addition of cement to the mix and within 30 minutes of its discharge from the agitator.

Where vibrators of immersion type are used, contact with reinforcement and all inserts like ducts etc. shall be avoided.

7.2.8. **Construction joints :** Construction joints shall be avoided as far as possible and in no case the locations of such joints shall be changed or increased from those shown on the drawings, except with express approval of the Engineer. The joints shall be provided in a direction perpendicular to the member axis.

7.2.9. **Concreting under water**

7.2.9.1. Concrete shall not be placed in water having a temperature below 5 degrees Celsius. The temperature of the concrete, when deposited, shall not be less than 16 degrees Celsius, nor more than 40 degrees Celsius.

7.2.9.2. Coffer dams or forms shall be sufficiently tight to ensure still water conditions. Pumping shall not be done while concrete is being placed, or until 24 hours thereafter.

7.2.9.3. All under water concreting shall be carried out by tremie method only.The concreting when started should continue without interruption for the full height of the member being concreted.

7.2.9.4. The tremie pipe shall not be less than 200 mm in diameter. The upper end of the pipe shall be plugged with a wadding of gunny sacking or other approved material before delivering the concrete to the tremie pipe through the hopper; so that when the concrete is forced down from the hopper to the pipe, it will have the plug(and along with it any water in the pipe) down the pipe and out of the bottom end, thus establishing a continuous stream of concrete. It will be necessary to raise slowly the tremie in order to allow a uniform flow of concrete, but it shall not be emptied so that water is not allowed to enter above the concrete in the pipe. At no time the tip of the tremie shall be above the concrete level.

7.2.10. **Protection and curing :** Curing and protection of concrete shall start immediately after compaction of the concrete.

Where members are of considerable size and length, with high cement content, accelerated curing methods may be applied.

7.2.10.1. **Water curing :** Exposed surfaces of concrete shall be kept continuously in a damp or wet condition by ponding or by covering with a layer of sacks, canvas, hessian or similar materials and shall be kept constantly wet for a period of not less than 14 days from the date of placing of concrete.

Sea water shall not be used for curing. Sea water shall not come into contact with concrete members unless it has attained adequate strength.

7.2.10.2. **Steam curing :** The initial application of the steam shall be after about four hours of placement of concrete to allow the initial set of the concrete to take place.

Where retarders are used, the waiting period before application of the steam shall be increased to about six hours.

When steam curing is discontinued, the ambient air temperature shall not drop at a rate exceeding 3 degrees Celsius per hour until a temperature of about 10 degrees Celsius above the temperature of the air to which the concrete will be exposed, has been reached.

The concrete shall not be exposed to temperatures below freezing for at least six days after curing.

7.2.10.3. **Curing compounds :** Curing compounds shall only be permitted in special circumstances with the approval of the Engineer. All concrete cured by this method shall receive two applications of the curing compound. Curing compounds shall not be used on any surface which requires further finishing/bonding. All construction joints shall be moist cured.

7.2.11. **Finishing :** Immediately after the removal of forms, exposed bars or bolts, if any, shall be cut inside the concrete member to a depth of at least 50 mm below the surface of the concrete and the resulting holes filled with cement mortar. All fins caused by form joints, all cavities produced by the removal of form ties and all other holes and depressions, honeycomb spots, broken edges or corners, and other defects, shall be thoroughly cleaned, saturated with water, and carefully pointed and rendered true with mortar of cement and fine aggregate mixed in the proportions used in the grade of concrete that is being finished and of as dry a consistency as is possible to use. Considerable pressure shall be applied in filling and pointing to ensure thorough filling in all voids. Surfaces which have been pointed shall be kept moist for a period of twenty four hours.

7.2.12. **Tolerances :** Tolerance for dimensions/shapes of various components should be as specified in relevant sections of MORT&H Specifications for Road & Bridge Works.

7.2.13. **Tests and standards of acceptance**

7.2.13.1. For sampling, testing and acceptance standards of concrete reference may be made to Section 1700 of Ministry's Specifications for Road and Bridge Works.'

7.2.13.2. Test specimen and sample strength : Three test specimens shall be made from each sample for testing at 28 days. Additional cubes may be required for various purposes such as to determine the strength of concrete at 7 days or for any other purpose.

The test strength of the sample shall be the average of the strength of 3 cubes. The individual variation should not be more than

± 15 per cent of the average.

7.2.13.3. **Frequency :** The minimum frequency of sampling of concrete of each grade shall be in accordance with following Table 7.6

Table 7.6

Quantity of Concrete in work (in cum)	No. of Samples
1 - 5	1
6 - 15	2
16 – 30	3
31 - 50	4
51 and above	4 plus one additional sample for each additional 50 m^3 of part thereof.

At least one sample shall be taken from each shift of work.

7.2.13.4. **Acceptance criteria**

Compressive strength

When both the following conditions are met, the concrete complies with the specified compressive strength.

(a) The mean strength determined from any group of four consecutive samples should exceed the specified characteristic compressive strength by 3 MPa.

(b) Strength of any sample is not less than the specified characteristic compressive strength minus 3 MPa.

The quantity of concrete represented by the test results include the batches from which the first and last samples were taken, together with all intervening batches.

7.3. **Formwork and Staging**

For form work and staging IRC:87 may be followed. However, following important points shall be kept in view.

The contractor shall furnish the design and drawing of complete formwork (i.e. the forms as well as their supports) for approval of the Engineer before any erection is taken up. Metal formwork shall preferably be used for achieving good finish. The formwork shall be robust and strong and the joints shall be leak-proof.

As far as practicable, clamps shall be used to hold the forms together. Where use of bolts is unavoidable minimum number of bolts shall be used and these shall be left projecting so that they can be withdrawn easily. Use of double threaded bolts shall be preferred.

Shuttering for walls, sloping members and thin sections of considerable height shall be provided with temporary openings to permit inspection and cleaning out before placing of concrete.

The formwork shall be constructed with precamber to the soffit to allow for deflection of the formwork. Pre-camber to allow for deflection of formwork shall be in addition to that indicated for the permanent structure in the drawings.

The formwork shall be coated with an approved release agent that will effectively prevent sticking and will not stain the concrete surface. Lubricating machine oils shall be prohibited for use of coating.

The formwork shall be inspected and approved by the Engineer before concreting is done.

Where not specifically mentioned on the drawings, the time of removal of formwork and staging shall be as under :

(a)	Walls, piers, abutments, columns and vertical faces of structural members	12 to 48 hours as may be decided by the Engineer
(b)	Soffits of slabs (with props left under)	3 days

(c)	Props (left under slabs)	14 days
(d)	Soffit of Girders (with props left under)	7 days
(e)	Props (left under girders)	21 days

7.4. **Placing of Reinforcement**

Reinforcing steel shall conform to the dimensions and shapes given in the approved Bar Bending Schedules.

Reinforcement bars shall be placed accurately in position as shown on the drawings. The bars, crossing one another shall be tied together at every intersection with binding wire (annealed) to make the skeleton of the reinforcement rigid such that the reinforcement does not get displaced during placing of concrete, or any other operation. The diameter of binding wire shall not be less than 1 mm.

Layers of reinforcement shall be separated by spacer bars at approximately one metre intervals. The minimum diameter of spacer bars shall be 12 mm or equal to maximum size of main reinforcement or maximum size of coarse aggregate, whichever is greater. No person shall be allowed to walk directly over the reinforcement placed in position.

Necessary stays, concrete/polymer cover blocks, metal chairs, metal hangers, supporting wires etc or other subsidiary reinforcement shall be provided to fix the reinforcement firmly in its correct position.

Placing and fixing of reinforcement shall be inspected and approved by the Engineer before concrete is deposited.

7.5. **Foundations**

7.5.1. **Open foundation :** Excavation for laying the foundation shall be carried out in accordance with Section 300 of Ministry's Specifications. Any depth excavated below the specified level shall be made good with M 15 concrete in case of foundation resting on soil and foundation grade concrete for foundations in rock.

Open foundation shall be constructed in dry conditions. When

the bearing surface is earth, a layer of M 15 concrete shall be provided below foundation concrete. The thickness of this layer shall be 100mm minimum unless otherwise specified.

Where water is met with an excavation, adequate measures such as bailing out, pumping, constructing diversion channels etc shall be taken to keep the foundation trenches dry and to protect the green concrete against damage.

All spaces excavated and not occupied by the foundation, shall be refilled with earth upto surface of surrounding ground. In case of excavation in rock, the annular space around foundation shall be filled with M 15 concrete upto the top of rock.

7.5.2. **Well foundations**

7.5.2.1. The construction procedure shall conform to the provisions contained in Section 1200 of Ministry's Specifications. Some important points for guidance are as follows:

(i) Fix up reference points, away from the zone of blow-ups/settlements resulting from well sinking and mark centrelines of the individual wells in longitudinal and transverse directions accurately.

(ii) Bench mark and reference points shall be checked regularly from permanent points fixed at site.

(iii) Cutting edge shall be laid on dry ground / sand island.

(iv) Sand island to be protected against scour until the sinking is done to a safe level.

(v) Floating caisson of steel can be adopted when construction of sand island is not feasible.

(vi) Use steel form of work for well curb.

(vii) Concreting in the well curb shall be done in one continuous operation.

(viii) Steining shall be cast only after sinking the curb to some extent so that it becomes stable.

(ix) The steining shall be built in one straight line from bottom to top.

(x) The height of the steining shall be calibrated by marking on outer faces in longitudinal and transverse directions (4 sides) with every metre mark in paint. Zero shall start from bottom of the cutting edge.

(xi) The well shall be sunk vertical as far as possible.

(xii) For sinking, material be excavated uniformly all round the dredge hole.

(xiii) De-watering should not be permitted as a means for sinking.

(xiv) A detailed statement with regard to the progress of well sinking shall be maintained at site as per *Appendix–13.*

(xv) Sinking history of well including tilt and shift, kentledge, dewatering, blasting done during sinking shall be maintained in the format given in *Appendix–14.*

(xvi) The depth of sump below the level of cutting edge shall be generally limited to one-sixth of the outer diameter/ least lateral dimensions of well in place. Normally, the depth of sump shall not exceed 3m unless otherwise specifically permitted by the Engineer.

(xvii) Bottom plugging shall be done with the help of tremie pipe. Additional 10 per cent cement shall be provided in the concrete for bottom plug.

(xviii) A record of the method of sinking adopted, bottlenecks encountered etc. may be kept as per proforma given in *Appendix-15.*

7.5.2.2. **Well sinking :** Sinking of well can be accomplished by the following methods:-

(i) Open grabbing with / without kentledge
(ii) Jackdown method
(iii) Pneumatic sinking of wells
(iv) Blasting

Blastings: Blasting may be employed with prior approval of competent authority to help sinking of well for breaking obstacles such as boulders or for levelling the rock layers for square seating of wells. Blasting may be resorted to only when other methods are found ineffective.

7.5.3. **Pile foundations :** The piles may be either pre-cast concrete piles or cast-in-situ driven or bored piles. The detailed procedure for construction of pile foundations shall conform to the specifications given in Section 1100 of M/o RT&H's Specifications and Clause 711 of IRC:78. Some of the points needing attention are as follows:

Pre-cast piles:

(i) For pre-cast piles, concrete shall be placed continuously until the completion of each pile.

(ii) In general, pre-cast concrete piles shall be lifted by means of a suitable bridle or sling attached to the pile but normally at points not more than 3m from the ends of the pile.

(iii) Pre-cast concrete piles cured with water shall not be driven for at least 28 days after casting (10 days with rapid hardening cement).

Cast-in-situ piles:

(i) Reinforcement cages shall be prepared in advance. However, in case during actual piling operation at site, the founding levels vary, necessitating either an increase

or reduction in the length of piles originally envisaged, the cage length should be adjusted.

(ii) The pre-fabricated reinforcement cage shall be lowered into position just prior to commencement of concreting which shall be carried out and completed without interruption.

(iii) As the concreting proceeds, the liners (if to be withdrawn) are withdrawn leaving sufficient head of concrete to prevent the entry of ground water or reduction of cross-section (necking) of the pile.

Test piles:

Test piles shall conform to Ministry's Specifications.

Test piles that are to become a part of the completed structure shall be installed with the same type of equipment that is proposed to be used for piling in the actual structure.

Test piles which are not to be incorporated in the completed structure shall be removed to at least 600mm below the proposed soffit level of pile cap and the remaining hole shall be back-filled with earth or other suitable material.

The piles shall be load tested in accordance with provisions laid down in Section 1100 of Ministry's Specifications for Road and Bridge Works.

7.6. Substructure

7.6.1. Materials shall conform to Section 1000 of Ministry's Specifications.

7.6.2. **Piers and abutments :** Masonry form work, concrete and reinforcement for piers and abutments shall conform to Section 2200 of Ministry's Specifications. In case of concrete piers, the number of horizontal construction joints shall be kept minimum. Construction joints shall be avoided in splash zones unless specifically permitted and provided they are treated in accordance with special

provisions. No vertical construction joint shall be provided.

In case of tall piers and abutments, use of slip form shall be preferred. The design, erection and dismantling of slip form shall be subject to special specifications which will be furnished by the contractor.

Surface of foundation/well cap/pile cap shall be scrapped with wire brush and all loose materials removed. In case reinforcing bars projecting from foundations are coated with cement slurry, the same shall be removed by tapping, hammering or wire brushing. Care shall be taken to remove all loose materials around reinforcements. The just before commencing masonry or concrete work, the surface shall be thoroughly wetted.

In case of solid abutments, (non-spill through type)weep holes shall be provided in conformity with Ministry's Specifications for Road & Bridge Works.

The surface finish shall be smooth except the earth face of abutment shall be rough finished.

In case of abutments likely to experience considerable movement on account of backfill of approaches and settlement of foundations, the construction of the abutment shall be followed by filling up of embankment in layers to the full neight to allow for the anticipated movement during construction period before casting of superstructure.

7.6.3. **Pier cap and abutment cap :** The surface of cap shall be finished smooth and shall have a slope for draining of water. For short span slab bridges with continuous support on pier caps the surface shall be cast horizontal. The top surface of the pedestal on which bearing are to be placed shall also be cast horizontally.

The surface on which elastomeric bearings are to be placed shall be wood float finished to a level plane which shall not vary more than 1.5 mm from straight edge placed in any direction across the area. The surface on which other bearings (steel bearings, pot bearings) are to be placed shall be cast about 25 mm below the bottom level of bearings.

7.6.4. **Dirt/ballast wall, return wall and wing wall :** In case of cantilever walls, no construction joint shall be permitted. Wherever, feasible, the concreting in cantilever walls shall be carried out in continuation of the ballast wall.

No horizontal construction joint shall be provided. If shown on drawings or directed by the engineers, vertical construction joints may be provided. Vertical expansion gap of 20 mm shall be provided in return wall/wing wall at every 10 m intervals. Weep holes shall be provided as prescribed for abutments.

The finish of the surface on the earth side shall be rough while the front face shall be smooth finished.

Architectural coping for wing wall/return wall in brick masonry shall conform to Section 1300 of Ministry's specifications.

7.6.5. Tolerances in concrete elements shall conform to Section 2208 of Ministry's Specifications.

7.7. Superstructure

7.7.1. **Concreting :** Concreting shall be done as per Section 2300 of Ministry's Specifications.

In case of solid slab superstructure resting on bearings, the latter shall be placed in position in accordance with the drawings, before casting of deck slab.

Where overlaid concrete wearing coat is to be provided, the top surface of the slab shall be finished rough.

The portions of deck slab near expansion joints shall be cast along with reinforcements and embedments for expansion joints. For this purpose, the portion of deck slab near expansion joints may be cast in a subsequent stage, if permitted by the Engineer.

No construction joint shall be provided between the bottom bulb and the web and also the web and the top flange forming part of the pre-cast girder.

In case of PSC superstructure cable layout and untensioned reinforcement shall be checked and approved by the Engineer before concreting. Sheathing material shall be examined for any possible punctures and proper sealing at overlaps against ingress of any mortar.

It should be ensured that during concreting, prestressing tendons and untensioned reinforcement are not displaced from their original position.

7.7.2. **Prestressing :** Before commencement of the prestressing, it shall be ensured that all the tendons are free to move between the jacking points.

The tendons shall be stressed at a gradual and steady rate and the extension recorded at each increment of jack pressure.

The extension of the tendons at the agreed pre-specified total force shall be within 5 per cent of the agreed calculated extension.

Any appreciable variation between the calculated extension and actual extension should be notified and settled in consultation with the Engineer-in-charge before proceeding with further tensioning.

Stressing shall be done from both ends unless one end prestressing is specified in the drawings.

Prestressing record of all the cables shall be maintained in the format given in Appendix 1800/II of Ministry's Specifications for roads & bridge works (third revision).

Efficiency of prestressing jack should be found before hand and catered for in the extension of cables.

7.7.3 **Grouting:** Grouting of cable ducts shall be carried out as per Appendix 1800/III of Ministry's Specifications.

Grouting shall be carried out as early as possible but not later than 2 weeks of stressing in tendon.

Before grouting, ducts shall be flushed with water for cleaning as well as for wetting the surfaces of the duct walls. Water used for flushing should be of same quality as used for grouting. It may, however, contain about 1 per cent of slaked lime or quick line. All water should be drained through the lowest vent pipe or by blowing compressed air through the duct.

Water/cement ratio of grout mix should be as low as possible, consistent with workability. This ratio should not normally exceed 0.45.

Mixing time depends upon the type of the mixer, but will normally be between 2 and 3 minutes. However, mixing should be for such a duration as to obtain uniform and thoroughly blended grout, without excessive temperature increase or loss of expansive properties of the admixtures. The grout should be continuously agitated until it is injected.

It is essential that the grout is maintained in a homogeneous state and of uniform consistency so that there is no separation of cement. Use of grout mixers to obtain a colloidal grout is essential.

The pump should be a positive displacement type and should be capable of ejecting the grout in a continuous operation and not by way of pulses. The grout pump must be fitted with a pressure gauge to enable pressure of injection to be controlled. The minimum pressure at which the grout should be pumped shall be 0.3 MPa and the grout pump must have a relief arrangement for bypass of the grout in case of build-up of pressure beyond 1 MPa. The capacity of the grout pump should be such as to achieve forward speed of grout of around 5 to 10m per minute. The slow rates are preferable as they reduce the possibility of occurrence of voids.

Pumping of grout should continue till the mix coming out at the other end is of the same consistency.

Grouting record should be maintained in the format given at Appendix 1800 / IV of Ministry's Specifications (Third revision)-1995.

7.8. **Bearings :** Bearings shall conform to the provisions contained under Section 200 of Ministry's Specifications for Road & Bridge Works published in April 1995 and IRC:83 – Part I & Part II. However, some of the important points about installation are as follows:

7.8.1. **Steel bearings/Pot cum PTFE/Spherical/Pin Bearings/ Roller-cum-Rider :**

(a) Roller and rocker bearings shall be so placed that their axes of rotations are horizontal and normal to the direction of movement of the members they support. Upper and lower bearing plates shall be set horizontal in both directions.

(b) During installation, the roller bearings shall be pre-set with respect to the bearing axis to account for the movement due to the following:

(i) Temperature variation between the average temperature prevailing at the time of installation and the mean design temperature.

(ii) Shrinkage, creep and elastic shortening (in case of prestressed superstructure).

(c) For bridges in gradient, the bearing plates shall be placed in a horizontal plane.

(d) On supporting structures, pockets shall be provided to receive anchor bolts; one side of the pocket shall project beyond the bearing plate. The pocket shall be filled with mortar of mix 1:1 and the concrete bearing area also shall be finished level by a thin and stiff mortar pad of mix 1:1 (the thickness not exceeding 12mm) just before placing of bearing assemblies or bottom plate on the concrete seat.

(e) In case of pre-cast girders a recess of 6mm shall be provided on the underside with a level finish for housing

the bearing plate. A thin and stiff mortar pad of mix 1:1 with thickness not exceeding 3mm shall be provided over the top plate before lowering the pre-cast beam in position in order to ensure full and even pressure on the plate surface.

(f) All concrete surfaces to be in contact with the mortar shall be thoroughly cleaned and kept saturated with water for a period not less than 24 hours before placing mortar.

(g) It shall be ensured that while placing the girders, the bearings are in their exact positions as indicated on the approved drawing and not displaced therefrom.

7.8.2. **Elastomeric bearings**

(a) All bearings of the lot shall be visually inspected for any defects in surface finish, shape or any other discernable superficial defects.

(b) Each elastomeric bearing shall be clearly labelled or marked. The bearing shall be wrapped in a cover. They shall be packed in timber crates with suitable arrangement to prevent their movement and to protect corners and edges.

(c) Care shall be taken to avoid mechanical damage, contamination with oil, grease, dirt, undue exposure to sunlight and weather to the bearings during transport storage and handling prior to and during installation.

(d) Bearings must be placed between the two horizontal surfaces (maximum tolerance 0.2 per cent perpendicular to the load) and at true plan position of their control lines marked on receiving surfaces (maximum tolerance +3mm).

(e) Concrete surfaces shall be free from impurities like oil, grease, dust and also local irregularities (maximum tolerance +1mm in height).

7.9. **Expansion Joints :** The fabrication and fixing of expansion joints shall be as per approved drawings and in accordance with Section 2600 of Ministry's Specifications and with manufacturers' recommendations and Ministry's interim specifications issued vide letter No. RW/NH/34059/1/96 dt 31/03/97 with amendment issued from time to time.

7.10. **Materials**

7.10.1. **Cement :** Cements manufactured in the country are covered by the following Indian standards:

(i)	Ordinary Portland Cement (33 grade)	IS :269
(ii)	Rapid Hardening Portland Cement	IS 8041
(iii)	Blast Furnace Slag Cement	IS : 455
(iv)	Ordinary Portland Cement (43 grade)	IS : 8112
(v)	Portland Pozzolana Cement	IS :1489 Part I
(vi)	Ordinary Portland Cement (53 grade)	IS : 12269
(vii)	Sulphate Resistant Portland Cement	IS : 12330
(viii)	Low Heat Portland Cement	IS: 12600

- OPC 43 or 53 grade when used, the minimum cement content mentioned from durability consideration shall be ensured.
- For PSC members cement listed at Sl.No. (i), (iv), (vi), (vii) confirming to IS:269, IS:8112, IS:12269 and IS:12330.
- Portland pozzoland cement (IS: 1489) may be permitted only in plain concrete members.
- Sulphate resistant cement (IS: 12330) shall be used when Sodium Sulphate and Magnesium Sulphate are present in large concentrations detrimental to concrete.

Before taking any supply, manufacturers' certificate that the cement conforms to the requirements of BIS is to be obtained. BIS certification of all cement supply is mandatory. The distinguishable identification marks put on the cement bags should also be taken which would help in identifying bags of one type of cement from other type.

It is not sufficient to rely solely on the manufacturers' test certificate. Independent testing of every consignment of cement shall be done prior to use.

7.10.2. **Coarse aggregate:** Coarse aggregates shall consist of clean, hard, strong, dense, non-porous crushed stone, crushed gravel, natural gravel or other approved inert materials. These shall not consist pieces of disintegrated stones, soft, flaky, elongated particles, salt, alkali, vegetable matter or other deleterious materials. Coarse aggregates having positive alkali-silica reaction shall not be used.

Coarse aggregates shall conform to IS: 383 and tests for conformity shall be carried out as per IS: 2386 parts I to VIII.

The maximum value for flakiness index for coarse aggregates shall not exceed 35 per cent. The coarse aggregates shall satisfy the following requirements for grading:

Requirements of coarse aggregates

IS Sieve Size	Per cent by weight passing the sieve		
	40mm	20mm	12.5mm
63mm	100	-	-
40mm	95 - 100	100	-
20mm	30 - 70	95 - 100	100
12.5mm	-	-	90 - 100
10mm	10 - 35	25 - 55	40 - 85
4.75mm	0 - 5	0 - 10	0 - 10

7.10.3. **Sand/fine aggregates:** Fine aggregates shall consist of natural sand or hard pieces of crushed stone or gravel or combination thereof. They shall be clean and should not contain mica or other deleterious materials in such quantities as to reduce the strength and durability of the concrete or to attack the embedded steel.

All fine aggregates shall conform to IS: 383 and tests for conformity shall be carried out as per IS: 2386 (Part I to VIII).

The fineness modulus shall neither be less than 2.0 nor greater than 3.5.

Sand/fine aggregate shall conform to the following grading requirement:

IS Sieve Size	Per cent by weight passing the sieve		
	Zone I	Zone II	Zone III
10mm	100	100	100
4.75mm	90 – 100	90 – 100	90 – 100
2.36mm	60 – 95	75 – 100	85 – 100
1.18mm	30 – 70	55 – 90	75 – 100
600micron	15 – 34	35 – 59	60 – 79
300micron	5 – 20	8 – 30	12 – 40
150micron	0 – 10	0 – 10	0 – 10

7.10.4. **Steel**

7.10.4.1. Reinforcement/untensioned steel shall consist of the following grades:

Grade Designation	Bar type conforming to governing IS Specifications	Characteristic strength fy Mpa	Elastic Modulus Gpa
Fe 240	IS : 432 Part I Mild Steel bar	240	200
Fe 415	IS : 1786 High Yield Strength Deformed bars (HYSD)	415	200
Fe 500	IS1786 Deformed bars	500	200

Other grades of bars conforming to IS: 432 and IS: 1786 shall not be permitted. No re-rolled steel shall be permitted.

Fusion-bonded epoxy coated reinforcing bars shall meet the requirements of IS:13620 and additional requirements as per Clause 1009.3 of Ministry's Specifications. Wire fabric company to IS:1566 and TMT bars conforming to IS: 1786 can also be used.

7.10.4.2. **Steel for pre-stressing:** The pre-stressing steel shall conform to either of the following:

(a) Plain hard drawn steel wire conforming to IS: 1785 (Part I) and IS: 1785 (part II).
(b) Cold drawn indented wire conforming to IS: 6003.
(c) High tensile steel bar conforming to IS: 2090.
(d) Uncoated stress relieved strands conforming to IS: 6006.
(e) Uncoated stress relieved low relaxation strand conforming to IS: 14268.

7.10.4.3. **Cast steel:** Cast steel shall conform to grade 280-520 N of IS: 1030. For grey iron castings, Clause 1009 of Ministry's Specifications may be referred to.

7.10.4.4. **Structural steel:** All structural steel shall comply with the requirements of the relevant Indian Standards, viz, IS: 226, 961, 2062, 8500, 1148, 1149, 1161, 4923, 11587, 808, 1239, 1730, 1731, 1732 and 1852.

7.10.5 **Water:** Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkali, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Potable water is generally considered satisfactory for mixing concrete. Mixing and curing with sea water shall not be permitted. As a guide, the following concentrations represent the maximum permissible values:

(a) To neutralise 100ml sample of water, using phenolpthalein as an indicator, it should not require more than 5ml of 0.02 normal NaOH.

(b) To neutralise 100ml sample of water, using methly orange as an indicator, it should not require more than 25ml of 0.02 normal H_2SO_4

(c) The permissible limits for solids shall be as follows when tested in accordance with IS:3025:

	Permissible limits (max)
Organic	200 mg/lit
Inorganic	3000 mg/lit
Sulphates (SO_3)	400 mg/lit
Chlorides (Cl)	500 mg/lit*
Suspended matter	2000 mg/lit

* In case of plain cement concrete, the limit of chlorides may be increased upto 2000 mg/lit.

All samples of water (including potable water) shall be tested and suitable measures taken where necessary to ensure conformity of the water to the requirements stated herein.

(d) The pH value shall not be less than 6.

7.10.6. **Admixtures:** Admixtures shall conform to the requirements of IS:9103. In addition, the conditions mentioned in clause 1012 of Ministry's Specifications shall be satisfied.

Admixtures are used to modify the following properties:

(i) Workability of fresh concrete,

(ii) Pumpability,

(iii) High strength through reduction of water content.

Admixtures are usually added to mixing water just before mixing of the concrete or during the mixing operations. Admixtures are usually added as a percentage of the mass of the cement content of a mix. Admixtures are also used as accelerators, retarders and plasticisers (water reducing agents).

7.10.7. **Storage of materials**

7.10.7.1. **General:** All materials shall be stored in such a manner so as to prevent their deterioration or intrusion by foreign matter to ensure the preservation of their quality and fitness for the work.

7.10.7.2. **Aggregate:** Different sizes of coarse aggregates shall be stored in separate stock piles, sufficiently away from each other to prevent inter-mixing.

Aggregates should be stored on a clean, hard surface and not directly on the ground as material will be wasted and mud and dirt may get mixed with the concrete. When a hard surface is not available, it is advisable to spread a layer of lean concrete (such as one with an aggregate cement ratio of 1:9) over the ground on which the aggregates are to be stored. It should be laid with slopes to the edges so that water drains away from the stockpiles. The use of aggregates from the bottom of a stockpile should be avoided, as this part is usually saturated with water and may also contain an accumulation of dirt washed in from the higher layers.

7.10.7.3. **Cement:** Cement shall be stored above ground in perfectly dry and watertight sheds and shall be stocked not more than 8 bags high. Where storage containers are used, their capacity shall be adequate to cater to requirements at site and should be cleaned once every 3 to 4 months. Cement more than 3-4 months old shall invariably be tested before being used on the work.

The bags should be stocked such that the first batch **in** can be the first **out**.

7.10.7.4. **Steel:** The bars should be stored above the surface of the ground preferably in covered shade. If they are to be stored for long periods, some covering should be provided to keep off the rain. Slight rusting cannot usually be avoided but bars that are rusty should be freed from loose rust (brushing with a wire brush is the best means of doing this); otherwise, the concrete will not grip the steel properly and the strength of the unit may be seriously reduced.

The bars should be stacked in such a manner that the lengths

and sizes required can be found easily. Bars should be marked with their original bar list number on a paper covered metal label. In this way, the bar bender can find the correct group of bars without having to move several tons of the wrong type.

7.10.7.5. **Prestressing materials:** All prestressing steel, sheathing, anchorages and sleeves or coupling must be protected during transportation, handling and storage. The prestressing steel, sheathing and other accessories must be stored under cover from rain or damp ground and protected from the ambient atmosphere if it is likely to be aggressive. Storage at site must be kept to the absolute minimum.

Prestressing steel shall be stacked in a closed store having single door with double locking arrangements and no windows. Also the air inside the store shall be kept dry as far as possible by using various means to the satisfaction of the Engineer. Also instrument measuring the air humidity shall be installed inside the store. This is with a view to eliminating the possibility of initial rusting of prestressing steel during storage.

7.10.7.6. **Water:** Water shall be stored in containers/tanks covered at top and cleaned at regular intervals in order to prevent intrusion of foreign matter or growth of organic matter. Water from shallow, muddy or marshy surface shall not be permitted. The intake pipe shall be enclosed to exclude silt, mud, grass and other solid materials and there shall be minimum depth of 0.60m of water below the intake at all times.

7.10.8. **Tests and standards of acceptance of material:** The contractor shall furnish test certificates from the supplier of materials along with each batch of material (s) delivered to site.

The contractor shall set up a field laboratory with necessary equipments.

The testing of all the materials shall be carried out by the Engineer or his representative at site.

Tests which cannot be carried out in the field laboratory have to be got done from recognised laboratory.

Testing at site:

Sand:

(1) Grading by sieve analysis.

(2) Fineness modulus.

(3) Silt test – with measuring cylinder filled with salt water solution (one teaspoonful to a half litre water). Fill the cylinder up to 50ml, mark and then pour the sand until the level of sand reaches 100 ml mark and the water level higher. Add more salt water till the level reaches 150 ml mark. Then shake the cylinder and keep on a level surface and tap gently until the top of the same layer is level. Allow to settle for 3 hrs and measure the height of the silt layer on top of the sand. This should not be more than 6 ml or 6 per cent of the height of sand.

(4) Organic impurities test – take 3 per cent solution of caustic soda (sodium hydroxide) in water in a graduated clear glass bottle of 350 ml. Fill it up with the sand upto 125 ml mark, add the caustic soda solution with shaking until the level comes to 310 ml mark. Shake the bottle vigorously and leave to stand for 24 hrs. Check the colour of the liquid on top, clear and light straw colour is acceptable. Darker colour show organic impurity.

(5) Moisture content – use any instrument known as 'speedy moisture tester' or by liquid displacement method or by the conventional method of weighing, drying and re-weighing.

Coarse aggregates:

(1) Grading by sieve analysis.
(2) Flakiness index.
(3) Crushing strength.
(4) Cleanliness i.e. impurities of clay, mud, vegetable matter, etc.
(5) Moisture content.

8. QUALITY SYSTEMS FOR ROAD BRIDGES

8. QUALITY SYSTEMS FOR ROAD BRIDGES

8.1. To ensure building of safe, serviceable, durable and economically viable bridges, it is necessary to have a strategy for management of human skills by way of quality system defining quality policy, quality assurance and quality audit. Guidelines on quality systems for road bridges have been evolved by IRC vide SP:47 – 1998 " to facilitate preparation of appropriate quality systems for new bridge projects and application of these guidelines will inculcate in all those involved in this building activity who provide the product or services expected of them consistently. These guidelines cover quality system for activities of bridge structure using concrete elements and include project preparation, design and drawing, construction and supervision, contract management, quality of materials and equipments used in construction and workmanship. The guidelines also stipulate organisational requirement for adoption of quality system by suppliers, purchasers, owners, approving authorities and consultants. These guidelines have been made applicable for all the bridge structures on National Highways and centrally financed schemes by the Ministry vide Circular No. RW/ NH-34066/5/S&R dated 20th Dec. 1999.

8.2. Depending upon the level of checking/cross checking and control required to provide adequate confidence four classes of quality assurance are mentioned below:-

Sl. No.	Clause of Quality Assurance	Clause nomenclature	Remarks
1.	Nominal QA	Q1	Not recommended for bridge works
2.	Normal QA	Q2	
3.	High QA	Q3	
4.	Extra high QA	Q4	

Since the degree of the requirement of the confidence for bridge construction is very high, nominal QA i.e. Class Q1 shall not be permitted in bridge construction. Thus, there will only be 3 clauses of QA for bridge construction, i.e. Q2, Q3 & Q4.

8.3. Prior to commencement of the project preparation stage, one of the three Quality Assurance (QA) class should be tentatively chosen for the project. The classification should be reviewed depending on site specific problems and types of solutions being evolved and at this stage, final selection of overall QA class of the project should be made. Simultaneously, decision regarding updation of class for some of the activities if found necessary should also be made. The word "bridges" includes flyovers, culverts and all such structures carrying road traffic. Following guidelines are to be adopted for selection of appropriate QA class for bridges:-

(1) No bridge should have QA below class Q-2.

(2) Q-2 class of QA can be adopted for following categories of bridges.

(a) Bridges upto 60 m length and having individual span length not exceeding 20 m.
(b) Bridges having deck area upto 480 sq.m.
(c) Construction materials: Plain or Reinforced concrete.

In order to cater to specific problems, some of the activities may be raised to Q-3 class.

(3) Q-3 class of QA can be adopted for following categories of bridges.

(a) Bridges having spans exceeding 20 m.
(b) Bridges having lengths more than 60 m, having individual span lengths not exceeding 45 m.
(c) Bridges having deck area exceeding 480 sq.m.
(d) Construction materials: Plain concrete, reinforced concrete or prestressed concrete.

For bridges across rivers which are shifting in nature or which present some problems of stability, and /or those having special foundation problems, some of the activities may be raised to higher class.

(4) Q-4 class of QA can be adopted for following categories of bridges :

(a) Bridges built with innovative design/construction/ materials such as those using very large spans, cable stay concept, high performance concrete, new prestressing systems etc. Separate Quality Assurance manual as appropriate to cover such design, materials/construction techniques should be prepared and defined in the tender document.

(b) Bridges at locations where no alternative routes are available nearby, or where disruption to traffic over long period is unacceptable, and where repair/replacement cost are considered very high.

After having decided the proper Quality Assurance class for the bridge under consideration, a system for Quality Assurance may be evolved and adhered to as per the guidelines given in IRC: SP : 47-1998 – "Guidelines on Quality System for Road Bridges".

9. PROJECT SCHEDULING AND MONITORING OF WORKS

9. PROJECT SCHEDULING AND MONITORING OF WORKS

9.1. Scheduling

For all important bridge projects, it is essential to have a CPM/ PERT chart for the entire project. Reference may be made to Special Publication No. SP-14 of IRC Construction agency should submit the chart preferably along with the tender, and in any case before commencement of work. For minor bridges, bar charts fixing the targets for the major activities along with the construction schedule may be submitted.

The various activities involved in the completion of the project right from the award of work to its completion shall be identified both in terms of time and money as also the resources like manpower, T&P and materials etc., required for the completion of the activity, the entire purpose being to streamline the construction procedures and take advance action in respect of those activities which affect the subsequent activities and in particular, the activities in critical path, so as to avoid any delay arising in the completion of the project. The inter-dependency of different activities should be correctly shown and the activity durations considered shall be realistic. The CPM chart should be updated regularly as the work progresses.

Availability of resources, viz, manpower, material, plant and machinery and funds shall be clearly identified to enable their mobilization / procurement well in time.

9.2. Monitoring

9.2.1. To monitor the progress of the work at various stages, necessary data must be maintained at site showing the position of each activity, targets to be achieved, bottlenecks, if any, expenditure and position of funds, etc.

9.2.2. Monthly/quarterly progress reports may be prepared in the proforma prescribed by the Ministry and submitted regularly to the concerned officers for their information and for keeping a close watch on the progress of the work and the problems encountered in the field with a view to sort them out.

9.2.3. It is necessary to ensure simultaneous completion of a bridge work and its approaches. Accordingly, progress made on the approaches may also be indicated.

9.3. **Documentation**

Record of design and drawings as approved for construction and completion of drawings as per actual construction should be maintained meticulously at the division / circle office or at Chief Engineer's office. To save storage space, micro-filming system may be introduced.

10. INSPECTION AND MAINTENANCE OF BRIDGES

10. INSPECTION AND MAINTENANCE OF BRIDGES

10.1. General

The highway structures either old or new have to be maintained in a traffic-worthy condition to facilitate uninterrupted flow of traffic. To ensure this requirement, it is necessary that periodic maintenance inspections are made by responsible officers so that where necessary, timely remedial steps are taken.

10.2. Guidelines for inspection

Detailed guidelines for highway bridge inspection and maintenance are contained in IRC Special Publication No 35 "Guidelines for Inspection and Maintenance of Bridges", IRC Special Publication No 18 "Manual for Highway Bridge Maintenance Inspection" and IRC:52-1998 "Bridge Inspection's Reference Manual" which may be followed. These manuals provide guidance on the types of inspection, time and frequency of the inspection, status of the inspecting officer and features to be inspected and follow-up action to be taken on the inspection report etc.

10.3. Maintenance of records of bridges

(i) For maintenance of records of bridges, firstly a bridge register should be maintained. However, for each bridge, there must be two reports –

(a) Original bridge report,
(b) Inspection report.

The original bridge report shall be maintained on the basis of the completion drawings supplemented wherever necessary by site inspection. However, in case of old bridges where sufficient data is not available, the inspection should be undertaken by a responsible officer for compiling the same. The items to be covered in the original bridge report should be those listed in IRC Manuals referred above.

(ii) **Maintenance manual for major bridges :** The Engineers who are associated with the construction of the project should also prepare detailed maintenance manual indicating the critical points needing special attention by the Engineers who may be looking after the maintenance of the bridge subsequently during its service period.

10.4. Types of Inspection

Inspection of bridges should be undertaken as per the following classification.

10.4.1. Routine inspection

10.4.1.1. The purpose of this inspection is to determine fairly obvious deficiencies in the bridge structure which might lead to traffic accidents or cause high maintenance and repairs cost, if not attended promptly. The routine inspection will rely mainly on visual assessment using conventional standard tools (Appendix 4 of IRC SP: 35). The frequency of routine inspection shall be at least once a year but preferably twice a year before and after monsoon. However, bridges located in high altitude terrain prone to effects of land slides and bridges in severe exposure conditions shall be inspected twice a year, i.e. before and after monsoon. To facilitate proper routine inspection, a simple check-list is suggested . (Refer *Appendix 5* of IRC:SP: 35)

10.4.1.2. Routine inspection shall be carried out by competent and qualified engineers. In general, the status of the inspecting officer may be as mentioned below but the same can be altered depending upon the importance of the work.

	Bridge length	Status of the inspecting officer of the State PWD
(a)	Up to 30m	Junior Engineer.
(b)	From 30m to 60m	Asstt Engineer/Asstt Executive Engineer.

c)	From 60m to 200m	Executive Engineer.
d)	Above 200m and all prestressed concrete, continuous structures, suspension bridges, cable stayed bridges and special structures.	Superintending Engineer in all cases and in addition Chief Engineer for bridges above 500m in length.

10.4.2. **Principal inspection:** This is a more intensive and detailed inspection involving close examination of elements of structure with a purpose to determine the nature and degree of distress in any component of a bridge. It will primarily be close visual assessment supplemented by standard instrumented aids. Detailed inspection of foundation should also be included and may involve underwater inspection wherever appropriate. The first principal inspection shall be conducted before the expiry of defect liability period of contract but not later than 6 months after completion and opening of the bridge to traffic. The frequency of principal inspection thereafter shall not be more than 3 years. This inspection shall be carried out by a senior level engineer against a comprehensive check-list.

10.4.3. **Special inspection:** This shall be undertaken in the event of unusual occurrences such as strong earthquake, accidents, passage of unusual loads or floods, heavy impact of barges or floating debris on substructure and/or foundations, major weaknesses noticed during routine or principal inspection, unusual settlement of foundations and substantial changes of traffic pattern. When any bridge of similar design and constructed almost at the same time are showing some distresses, all such bridges may be subjected to special inspections. Such inspections may require a good deal of supplementary testing and structural analysis and will invariably require detailed involvement of design organisations and experts in the relevant fields who should be senior level engineers.

10.5. Inspection procedure

10.5.1. The activities scheduled during the inspection of the bridge should be planned in detail including sequence of inspection. Where mobile bridge inspection unit is used, the inspection should be carefully planned before-hand so as to minimise the period of use of

such equipments as the hourly cost of use of such a unit is quite high and it obstructs one lane of traffic on the bridge.

10.5.2. The inspection should follow a pre-determined pattern to ensure that no component is overlooked. A typical pattern of inspection may be on the following basis:

Foundations,
Abutments,
Wing walls/returns,
Piers columns and bearings,
Soffits of the deck including beams,
Details under the deck,
Condition of road surface, drainage, parapets,
Expansion joints,
Condition of approaches,
Condition of protective works.

10.5.3. It is desirable that inspection should be undertaken in those periods of the year which offer the most critical evaluation of the performance of the structures as suggested below:

	Items	Time of inspection
(a)	Foundations, protective works, scour effects, maximum flood level, etc.	During and after monsoons
(b)	High structures	During and after season of high velocity wind.
(c)	Bearings and expansion joints	During extreme seasons and after floods.
(d)	Bridges in hilly terrain	Before and after monsoons.

10.5.4. **Underwater inspection:** Visual examination of the surface may be done after removing marine growth like coral deposits, algae, etc. Detailed inspection for obtaining more information of deteriorated areas should be done after clearing the surface growth

so as to enable closer inspection. Underwater inspection is a highly specialised activity and as such should be entrusted only to competent agencies experienced in underwater inspection. Such agencies should be fully briefed on the components to be inspected and the nature of defects to be inspected. Close circuit television may be used where the water is reasonably clear. Where visibility is poor, portable echo sounding equipment can be used to provide a reasonably accurate profile.

10.5.5. **Means of access:** Appropriate means of access are a pre-requisite for all the three forms of inspection. For every means of access, special emphasis shall be laid on safety, ease and convenience. Due consideration shall be given at the design stage itself to the provision of proper means of access taking into account individual requirements of the structure and its components such as type of structure, topographical, local and climatic conditions of the bridge site, height, minimum water level. The possible means of access can be of the following type:

(I) **Built-in access**:

(a) Man-hole,
(b) Built-in ladders,
(c) Permanent catwalks.

(II) **Semi-mobile access:**

(a) Access ladders,
(b) Catwalks,
(c) Platforms,
(d) Inspction pits,
(e) Planking, scaffolding, etc.
(f) Semi-stationery inspection equipment.

(III) **Mobile equipments:**

(a) Equipment operating under the bridge from river bed/water barges,
(b) Equipment operating from the bridge deck.
(c) **Mobile inspection unit:** This is a very versatile equipment for speedy inspection of large number

of bridges and wherever available shall be made use of. Ministry of Road Transport and Highways has also financed few mobile inspection units which are being used jointly by State PWDs for inspection of NH bridges.

10.6. **Assessment Techniques and Equipment**

Various techniques and equipments for detailed inspection analysis and quantification of distresses and their repair techniques has been covered in detail under Chapter 11 and may be referred to.

10.7. **Inspection Report**

The inspection report shall be in the prescribed formats. Properly referenced sketches or photographs should be used to illustrate the defects and condition of the bridge. Free hand sketches should be made during the inspection at the site itself. The size and location of the defects should be dimensioned though the sketch itself need not be to scale. For taking photographs, reference number of the bridge and the location of the defects may be written in colour at the appropriate place on the bridge. Apart from reporting defects and deficiencies any proposals or recommendations for strengthening and repairs of the affected components should also be included.

10.8. **Follow-up action**

10.8.1. Minor points or shortcomings noticed during inspection shall be immediately attended to by the Engineer-in-charge. However, in case of any important or major shortcoming / distress noticed either during routine inspection or principal inspection, the matter shall be reported to the senior level engineer and the latter should decide further line of action in consultation with the Design Organisations or Design Consultants, if he considers it necessary, and give detailed instructions as to whether special inspection is called for.

10.8.2. If during the inspections any bridge is found to indicate distress of serious nature leading to doubt about structural adequacy, the bridge will have to be evaluated for its load carrying capacity.

10.8.3. If the assessment shows the bridge to be inadequate for the design loads, one or more of the following actions should be taken:

(i) The load on bridge should be restricted to its assessed capacity. The condition of the bridge should be monitored by special inspection at intervals not exceeding 6 months.

(ii) The bridge should be closed for all traffic where the rated capacity of the bridge is lower than the lowest level of traffic load expected to ply on it.

(iii) Replacement or strengthening of the bridge or its affected part should be undertaken.

10.9. Maintenance Operations

10.9.1. These operations can be of two types, viz, ordinary maintenance operations and specialised maintenance operations. However, it must be admitted that the line separating them is rather a fine one.

10.9.2. **Salient aspects of maintenance of bridges:** Following important points may be kept in view for maintenance of bridges.

10.9.2.1. **Bridges in severe exposure condition**: Concrete members mainly in the coastal region are most vulnerable to corrosion. All such bridges shall be inspected at least twice a year (before and after monsoons) to ascertain if there are any signs of distress such as appearance of stains, cracks, spalling etc and action taken to remedy such defects in the past. Such bridges shall be kept under constant observations by resorting to frequent inspections and further remedial measures taken as considered necessary.

10.9.2.2. **Bridges across major alluvial rivers**: In case of major bridges built across alluvial rivers, deep scour may occur near some of the piers even with discharges much smaller than the design discharge. Such deep scour may result in tilting of foundations and consequent damage to various components of the bridges. In order to avoid such situations, soundings before, during and after each flood at all foundation locations for all bridges built across major rivers

with alluvial beds (foundations seated on soils) may be taken to ascertain if any excessive scour is taking place.

10.9.2.3. In case of excessive scour (beyond design level of scour), appropriate protective steps like dumping of boulders around the foundation locations or full fledged garlanding of the foundations may have to be resorted to, after obtaining necessary approval of competent authority.

10.9.2.4. In some cases, it may even be found necessary to train the river and guide the flow more uniformly through the various openings by means of proper training works, such as guide bunds or spurs, etc.

10.9.2.5. Since even small settlement of foundations may adversely affect the safety of the superstructure resting on bearings, particularly cut roller bearings, it is suggested that suitable concrete blocks/wooden packings be provided under the beams near the bearings to ensure that in the event of the superstructure getting dislodged from bearings, it would ultimately rest on such concrete blocks/wooden packings, avoiding the risk of a total collapse. Also observations on the movements and tilts of rollers be periodically made and permanent record of the same maintained. If in case the bearings are found to be in a critical condition, immediate action has to be taken for lifting the spans and resetting the bearings.

10.9.3. **Maintenance of submersible bridges:** The submersible bridges need greater maintenance effort compared to high level bridges specially after submergence. Normally, every major submersible bridge has its own maintenance manual giving guidelines for information to be collected, checks to be conducted and the locations where a constant vigil is required during and after the submergence. In case there is no manual, the following guidelines may be adopted for the maintenance of submersible bridges.

10.9.3.1. As soon as the water level in the river reaches the specified level, all traffic on the bridge shall be suspended till it recedes to a safer level.

10.9.3.2. Normally, vents are provided in the superstructure for submersible bridges for the passage of air/water during the

submergence. Before floods, these vents should be carefully inspected and cleaned if found chocked. After receding of floods, the entire superstructure shall be cleaned of the silt deposit and the vents shall be cleaned free of debris, vegetation etc. The superstructure shall be carefully examined after the submergence for any signs of distress or cracks and any remedial measures if necessary, taken.

10.9.3.3. Normally, the submersible bridges are provided with collapsible type of railings. The collapsible railings should be lowered as soon as the water in river attains the specified level and re-fixed after the water level has receded.

10.9.4. **Protective works**

10.9.4.1. The following points may be kept in view for inspection and maintenance of protective works:

(a) Most careful patrolling and watch is necessary during each flood season especially the first flood season to detect any weakness in construction and to take corrective action promptly.

(b) The Engineer-in-charge should acquaint himself with the past history of the protective works and the behaviour of the river.

(c) It is advisable to have a reserve quantity of stone which can be used in case of any emergency. A part of the stone may be stacked on the guide bund itself and a part in the nearest store from where it can be loaded and transported quickly to site. The quantity of reserve boulders would depend upon the site conditions. However, 2 per cent of the total quantity of boulders used in apron and slope pitching may be kept as reserve in stock for emergent use.

(d) During flood season it is advisable to have regular patrolling of the guide bund and the approach banks and proper action taken when abnormal swirls, eddies or scour are apprehended. Any small rain cuts or displacement by waves along the guide bund or the

approach bank must be repaired immediately as there is always the danger of a small cut developing into a major disaster, if not attended to.

(e) Any settlement in the approach road or bridge or slip in the slope needs immediate attention.

(f) Soundings preferably with the help of an echo sounder shall be taken near the guide bund when the river is in flood.

10.9.4.2. **Miscellaneous items**

(a) Elements like wearing coat, drainage spouts, hand rails, footpaths and construction joints should be inspected to see whether their performance is satisfactory. Surface condition such as cracks, spalling of concrete, disintegration etc. shall be looked for. Reinforcement should be inspected for corrosion. The condition of joints where pre-cast slabs are resting on kerbs shall be examined to see that no slab falls off the support. Any missing footpath slab shall be reported and replaced immediately so that any pedestrian does not fall into the gap caused by the absence of footpath slabs.

Hand rails near the maximum rotation point shall be inspected to see whether the gap between the two adjacent rail posts is widening or closing. Any lateral shifting of adjacent rail posts may be noted.

(b) Construction joints shall be examined to see whether there is a possibility for water to percolate through them. Important joints between main deck and kerb in the case of cantilever footpaths etc should be inspected carefully.

11. REPAIR AND REHABILITATION OF BRIDGES

11. REPAIR AND REHABILITATION OF BRIDGES

11.1. Introduction

11.1.1. Bridges are vital links in the highway network and if a bridge goes out of commission for any reason, the resultant disruption of traffic seriously affects the capacity and efficiency of the network. It is, therefore, essential that all bridges are kept in good condition and their rehabilitation and strengthening needs should be attended to as and when they arise. It is now well recognised that bridges not only require systematic maintenance but also strengthening or rehabilitation during their service life.

11.1.2. IRC:SP-40 "Guidelines on Techniques for Strengthening and Rehabilitation of Bridges" provides guidance on basic approach to repair and rehabilitation, identification, assessment and diagnosis of distress, repair materials and repair and strengthening techniques to be adopted in respect of concrete bridges. These guidelines may be followed while undertaking rehabilitation or strengthening of concrete bridges.

11.2. Major Causes of Distress

11.2.1. The single main cause of premature deterioration of concrete bridges is corrosion of reinforcing and prestressing steel. The problem of corrosion is of special significance in a tropical country like India, specially in hot and humid coastal environment which is highly conducive to corrosion. High humidity (more than 80 per cent R H), porosity of concrete, inadequacy of cover, cracks in cover concrete, use of rusted steel reinforcement without proper cleaning and lack of proper grouting in cable ducts are some of the factors which aggravate the problem. Another important cause of failure of prestressing steel is stress corrosion cracking or hydrogen embrittlement which occurs at high stress levels.

11.2.2. Other important causes of deterioration of concrete are aggregate alkali reaction and alkali silica reaction. It results either in pop-outs or cracks in concrete caused by expansion of reactive aggregate.

11.2.3. Concrete also suffers deterioration due to leaching action and sulphate attack.

11.2.4. Some other factors responsible for deterioration of concrete bridges are:

(i) Poor detailing,

(ii) Lack of strict quality control during execution,

(iii) Foundation movements due to scour, earth pressure or seismic activity,

(iv) Inadequate untensioned steel reinforcement in the anchorage zones of prestressing cables,

(v) Malfunctioning and damage to expansion joints,

(vi) Inadequate provision for movement due to temporary shrinkage and creek resulting in excessive displacement of bearings,

(vii) Poor drainage and lack of waterproofing of bridge decks,

(viii) Lack of preventive routine maintenance.

11.2.5. Bridges can also be damaged by land slides, fire and acts of war and insurgency.

11.3. **Signs of Distress**

Manifestation of distress in concrete bridges caused by various factors either individually or in combination are as follows:

- cracking due to corrosion or map cracking caused by chemical reaction between the mineral aggregates and cement paste; a serious problem in PSC bridges.
- scaling, which is local flaking or peeling-off of the surface portion of concrete exposing coarse aggregates.
- delaminations parallel to the concrete surface at or near

the level of reinforcing steel, indicating corrosion of steel and ultimate spalling of concrete.

- leaching in the form of accumulation of white salt or lime deposits on concrete surface.
- Spalling caused by corrosion of steel leading to local weakening, exposure of reinforcement, loss of prestress and ultimate structural failure.
- rust stains on concrete surfaces indicating corrosion of steel.
- deformation in the form of localised swelling or expansion indicating compressive failure of concrete or initial stages of spilling.
- excessive deflection of superstructure or movement of bearings indicated by closing or widening of expansion joints, tilting of piers / abutments and well foundations due to severe scour or any other reason.
- displacement of railings longitudinally or transversely.
- failure of flooring where provided.

11.4. **Steps Involved in Repair and Rehabilitation**

Various steps involved in arriving at an appropriate solution to the problem of a distressed bridge and implementation of remedial measures can be broadly identified as:

(1) Identify signs of distress and need for rehabilitation through routine inspection and study of construction drawings.

(2) Carrying out special inspection by expert team.

(3) Investigation of type and extent of distress and the causes thereof based on in-situ and laboratory tests.

(4) Analysis of investigation data supplemented by structural analysis and formulation of detailed plans for repair or strengthening.

(5) Implementation of repair or strengthening measures.

(6) Documentation of repair works done.

(7) Evaluation and monitoring of rehabilitation measures.

11.5. Investigation of Distress

11.5.1. Investigations should be carried out under the supervision of an experienced engineer who can interpret the initial test results, modify the procedure, number and type of tests, if found necessary at any stage.

11.5.2. **Planning:** At any planning stage, it is necessary to establish strategy and scope of investigations in detail including the type of access required, traffic management, equipment and manpower needed and selection of test procedures so that the resources to be mobilized for the bridge including design, drawings and specifications, maintenance records and previous reports relating to the condition of the bridge should also be obtained from various sources for study and evaluation.

11.5.3. **Inspection:** The technical personnel responsible for bridge inspection should be well trained and experienced so as to correctly interpret the observations relating to distress in various components of the structure. A visual survey complemented by a judicious selection of techniques for further investigation of defects, already identified, is a sound approach to any rehabilitation problem. Careful and systematic close visual inspection allows identification of most common forms of deterioration. However, such inspection can be carried out only on exposed surfaces of concrete. A check-list of various items to be covered in inspections is given in IRC:SP-35 "Guidelines for Inspection and Maintenance of Bridges".

11.5.4. Testing

11.5.4.1. A variety of non-destructive / destructive testing and evaluation methods are available for investigating different properties of concrete in addition to the vital visual inspection described earlier. Tests are aimed at assessment of strength and other properties and to locate and obtain comparative results indicating permeable regions, cracks or laminations and areas of lower integrity than the rest.

For various testing methods and their applicability to detect different forms of defects or deterioration in a concrete bridge structure, reference may be made to IRC:SP-40.

Some of the commonly used testing / evaluation methods are brought out as under:

11.5.4.2. **Non-destructive tests (NDT)**

(i) Rebound and penetration tests: These tests are used to assess the comprehensive strength, uniformity and quality of concrete. Schmidt Hammer and Windsor probes are commonly used devices.

(ii) **Ultrasonic pulse velocity measurement:** Pulse velocity measurements are used to assess the homogeneity of concrete, presence of cracks, voids, etc. quality of concrete relative to standard requirements, quality of concrete of one element relative to another and elastic modulus values of concrete.

(iii) **Determination of concrete cover:** Concrete cover can be measured with the help of covermeters or pachometer which are portable battery operated magnetic devices and are designed to detect the position of reinforcement and measure depth of concrete cover.

(iv) **Resistivity test:** The procedure involves measuring the resistance between the reinforcing steel and concrete surface by four-electrode method common in geophysical testing and provides an indication of the **rate of corrosion** in reinforcing steel.

(v) **Half cell potential measurement:** When steel corrodes in carbonated or chloride contaminated concrete, a potential difference exists between the anodic half cell areas and cathodic half cell on the steel. This difference in electric potential in the corrosion cell can be measured in a moist concrete by placing a copper / copper sulphate half cell on the concrete surface and measuring the potential difference between the half cell and the steel reinforcement with the help of a standard reference cell. The method gives indication of corrosion of reinforcement at the time of measurement but gives no information about rate of corrosion and the results are

influenced by changes in environmental conditions. The test is, however, rapid, inexpensive and relatively easy and extremely useful in assessing corrosion performance of a bridge when used in conjunction with data from other tests, i.e. resistivity and chloride content tests. This is one of the most widely used methods of electro-chemical testing of concrete structures.

(vi) **Gamma radiography:** Gamma radiographic technique is used for detecting voids in grout and defects in prestressing strands or wires which are broken or out of position. Gamma radiography of concrete is quite expensive and has health hazards from radiation and should be used only with proper precautionary measures. In the Indian context, this has to be done under the guidance of Bhabha Atomic Research Centre (BARC).

11.5.4.3. **Destructive/partially destructive tests:** Most of the destructive tests are done by taking concrete core samples drilled from the structure using a coring machine. Portable compact core drilling machines are today commercially available. Core drilling can, however, weaken the structure and should be done only under expert engineering guidance.

(i) **Carbonation:** Depth of carbonation in a concrete bridge component can be measured by spraying freshly broken concrete surfaces or cores with a 2 per cent solution of phenophthalein in ethanol. The solution is a pH indicator with colour change occuring around pH 10. Megenta areas of the exposed concrete surface after spraying represent uncarbonated concrete surface and the colourless areas represent carbonated concrete.

(ii) **Moisture content:** Moisture content at the level of steel reinforcement may be determined from concrete samples taken in the field and oven-dried in the laboratory.

(iii) **Pull out strength:** It is possible to assess the compressive strength of hardened concrete by co-relating it to the pulling force (for pulling embedded metal devices inserted in concrete by casting or drilling). It is, however,

difficult to get reliable data for making a proper co-relating and assessment.

11.5.4.4. **Laboratory tests:** The following are some of the main tests conducted in the laboratory on representative core samples of concrete and steel to supplement the results of visual observations and field tests:

- Compressive strength of concrete
- Cement content and air voids in concrete
- Static and dynamic modulus of elasticity
- Splitting tensile strength
- Petrographic examination of aggregates to check alkali aggregate reaction
- Chloride ion penetration in concrete. (Rapid tests for in-situ-chloride determination have already been introduced in Denmark)
- Tensile strength of reinforcing steel
- Sulphate content
- Permeability testing

11.6. Formulation of Repair Plans

11.6.1. The data from the investigations form the basis of the decision regarding selection of an appropriate rehabilitation plan out of the following available options:

- Whether to go for total replacement if the damages are too extensive and the cost of repair is prohibitive to take up.
- Localised repairs in the structure.
- Rehabilitation and / or strengthening.

11.6.2. The analysis of results of condition survey, detailed investigation and structural assessment enables the engineer to know:

(a) Whether there is a risk of failure of the damaged structure.
(b) Whether damages have stabilised or are likely to propagate further with time and repeated loading.
(c) Whether or not an economically effective repair plan

can limit or contain damages and enhance the effective service life of a structure.

(d) Degree of urgency required to implement a repair plan.

(e) Whether it is necessary to evaluate load carrying capacity of the bridge by load tests or otherwise.

11.6.3. Many a times, accurate structural analysis may not be possible for the assessment of both the existing strength as well as extent of repairs or strengthening required. The designer, therefore, has to be very judicious in his approach. Two things should be clearly understood:

(a) Deterioration mechanisms in the structure and influencing parameters must be identified in order to allow for a repair procedure, which can slow down or stop on-going deterioration.

(b) Repairs do not necessarily have to reinstate to initial level of quality and performance. A target quality of repair in terms of performance and extended service life should be fixed and the aim of repairs should be to achieve this target only.

11.6.4. Some of the important criteria for deciding the most appropriate rehabilitation plan from the available options may be identified as:

- Reliability and technical feasibility.
- Availability of expertise.
- Cost of repairs/rehabilitation for both short - term and long - term measures.
- Importance of the bridge in terms of political and socio-economic considerations.
- Estimate of residual life of the bridge and life expectancy anticipated for various available options.
- Risks involved with any changes in safety level or reduction in load carrying capacity.
- Availability and efficacy of repair materials and equipments.
- Feasibility of traffic diversion or duation of lane closures so as to cause minimum inconvenience to traffic.
- Access for repairs.

- Time involved in implementing the repair plan.
- Need for enhancing load carrying capacity.
- Availability of expert supervision during implementation of rehabilitation measures.
- The technique should be robust and not too sensitive to quality of workmanship and materials.
- The technique and materials should be resistant to environmental changes.
- The technique should involve preferably proven technology and new ideas and novel methods should be introduced with care and on trial basis.

11.6.5. After results of investigation have been analysed and the elements of repair plan decided, detailed working drawings have to be prepared for carrying out the necessary repairs at site. The drawings should give clear and exhaustive instructions regarding various procedures to be followed during execution of the repair plan. In addition, detailed specifications have to be drawn up for the materials and equipments to be used on the work. A scheme of quality assurance of the entire rehabilitation work should also be prepared.

11.7. **Repair and Rehabilitation Techniques**

11.7.1. **Repair materials**

11.7.1.1. Selection of a repair material must be based on an evaluation of damage, characteristics of the repair material and local conditions. Repair material must be compatible with the concrete being repaired. A wide variety of materials differing in cost and performance are today available for repair and maintenance of concrete. These are low viscosity polymers, very rapid setting cement, special concrete for overlays, apart from portland cement mortar or concrete. The final selection depends on many factors such as physical and chemical properties, mechanical response, long term durability, cost and record of field performance. Basically, the repair materials can be grouped into:

- Cementitious system,
- Polymer modified cementitious system,
- Polymer concrete system,
- Reactive thermosetting resin system.

11.7.1.2. The following are some major repair materials currently used for repair / rehabilitation or strengthening of bridges.

(i) Unmodified portland cement mortar or grout: These are generally mixtures of cement and suitable aggregates.

(ii) Latex modified portland cement mortar or concrete: These are portland cement mortar or concrete modified by addition of a latex emulsion. Long term strength is same as conventional mortar/concrete with same quantity of cement but chloride ingress can be reduced due to lower water-cement ratio. These are suitable for use in members with thickness greater than 13mm but are not recommended in thinner section.

(iii) Epoxy resin compound: Because of their property of high strength after setting, excellent adhesion to concrete surface and high chemical resistance, epoxy resin mortars and grouts are extremely useful for repairs. These are currently being used for anti-corrosive coating for reinforcing steel, painting of exposed concrete surfaces, patch repair of cracks and pressure grouting of cracks and voids. Epoxy adhesives are used for bonding steel plates externally to the concrete surfaces. Epoxy resins are available in a variety of formulation for use at different temperatures.

(iv) Polymer concrete: Although other materials have been useful to make polymer concrete, the most successful has been either an epoxy system with curing agents or methyl meta-acrylate monomer with an initiator and promoter. The epoxy systems are widely available in prepared formulations. Methyl meta - acrylate systems can be formulated by the user or pre-packaged systems can be used. Polymer concrete composites provide excellent means of protection to damaged concrete structures in the form of patching and surface coating. Rapid curing polymer concrete can accommodate traffic 2 to 3 hrs after placement. They possess very high strength and are reported to be more durable and reistant to most chemicals and acids in comparison to ordinary

concrete and exhibit excellent bond to parent concrete.

(v) Gunite/shotcrete: Synthetic silica shotcrete as a combination of polymer modified cement microsilica pozzolana and super plasticizer both as dry and wet mix can significantly improve quality of concrete. It is particularly suitable for patching large areas of shallow scaled or spilled concrete surfaces of beams, pier caps and underside of decks and replacing worn concrete surface. Properly applied shotcrete is a structurally adequate and durable material having excellent bonding property. Special variants of shotcretes result from the addition of fibre or synthetic resins.

(vi) Polyester resin mortars and grouts: Use of these materials is generally restricted to small repairs because of high shrinkage property exhibited. Common materials used are polyurethane resin, acryl resin and unsaturated polyster resin.

11.7.2. **Techniques of repair and strengthening**

11.7.2.1. Repair and remedial measures vary according to the location, form and severity of distress of deterioration. These may range from protective coatings or patch repairs in the case of mild deterioration to reconstruction or replacement of key elements in the case of severe distress.

11.7.2.2. Different repairs and strengthening techniques have been described in IRC:SP-40. Some commonly used techniques of repair and strengthening of distressed concrete bridges are as follows:

(i) Patching and grouting: Patching is carried out for repair of deep and wide cracks and for replacement of spalled concrete. Dry-pad mortar or conventional replacement mortar are normally used for filling cavities and around rebars. For very large areas shotcrete may be used. Cracks are also repaired by means of pressure grouting with epoxy resins for fine cracks and portland cement grout for larger cracks.

(ii) Hydrodemolition: Hydrodemolition technique involves selective removal of damaged concrete by means of one or more high speed water jets without using any abrasive. Hydrodemolition is unanimously accepted as the best process for concrete removal.

(iii) Vacuum grouting: Vacuum grouting with epoxy resin or cement grout can be used for filling up voids in cable ducts. The equipment used sucks the air out of the cavity and then via a relay valve presses the injection material into the cavity.

(iv) Epoxy injection: Epoxy injection for sealing fine cracks as small as 0.05mm has been successfully applied in the recent years. The epoxy is injected under pressure to penetrate the very fine and tortuous cracks that may exist. Quality of epoxy resin, the type of equipment and experience of the operating personnel are the factors governing the success of the operation.

(v) External prestressing: External prestressing consists of adding cables placed externally to the girders with new anchorages at suitable locations. It can be used to compensate the loss of prestress in the cables and partly/fully restore the bridge deck to its original serviceability level. It can also be used for strengthening a bridge deck to carry higher super-imposed dead and live load corresponding to increased vehicular loading.

(vi) As the external cables are fully exposed and do not have concrete cover, they should be encased in either a strong High Density Poly Ethylene (HDPE) tubing or rigid metallic pipe protected against corrosion by special coating. Pressure grouting of external prestressing cables after tensioning is essential. Special care should be taken while drilling holes or cutting recesses in the structure for fixing anchorage assemblies to ensure that the existing prestressing tendons are not damaged.

(vii) Epoxy bonded steel plates: Steel plates bonded to concrete surface with epoxy structural adhesive can strengthen RCC members in flexure and shear. The technique is relatively simple in application, speedy in execution without traffic disruption and involves little increase in dead weight. Bonded reinforcing in combination with post-tensioning affords a large variety of solutions for rehabilitation and strengthening problems.

(viii) Full depth concrete overlay/deck slab replacement: Where deterioration of large areas of concrete surface of bridge decks has occurred, it may not be possible to repair it by crack repair or patching. In such cases, a full depth concrete overlay may be required. Similarly, where the deck slab has become structurally weak due to loss of cross prestress or other reasons, complete replacement of the deck slab may have to be resorted to. The overlays can be of dense portland cement concrete with special quick setting admixtures of latex modified cement concrete. They should be bonded structurally to the underlying old concrete and should match the underlying concrete in thermal properties. In all such cases of overlays or deck replacement, the work can be carried out over half the width of the deck while permitting traffic on the other half. Traffic management or restrictions may be required during the course of the work.

11.8. **Repairs to Masonry Structures**

Existing masonry bridges are sometimes considered as historical landmarks and need preservation. Strengthening and widening will, therefore, mean maintaining the same appearance. Widening is usually not possible but strengthening can often be done. Strengthening of masonry bridges ensuring pleasant appearance is a delicate task and needs advice from experts in these fields. The following gives an idea of the general defects and remedial measures for such arch bridges in stone or brick masonry:-

(i) **Loss of Bond for the Crown stone**

Flat jacks have been successfully used for pushing the stone back to its original position. Generally, low pressure cement grouting is done to strengthen the old mortar. The mortar is sometimes replaced by epoxy mortar also, though epoxy is not ideal.

(ii) **Longitudinal cracks along the direction of traffic**

It is possible to rake mortar joints and refill with cement mortar. However, it must be mentioned that the depth of penetration is important as usually it is not possible to suspend traffic. If possible, the portion of earth fill could be removed to ensure that penetration is limited to masonry only. Fine cement grouting (injection) can be adopted for remedial measures. Generally it is cheaper and better to grout the cracks with cement than with epoxy.

(iii) **Transverse cracks**

Injection of cement will provide a good bond between stones and brick masonry.

(iv) **Strengthening of arch rings**

The arch ring can be strengthened in two ways – by adding material to the intrados or to the extrados. Adding to the intrados causes the least disturbance but is more difficult to complete successfully. Also it results in a reduction in head room or clearance which is often restricted and will, in most cases be the cause of new damage to the intrados as experienced on many bridges even where the headroom/clearance satisfies legal limits. Extra material may be placed by shuttering and pumping concrete (which is difficult to compact at the crown) or by fixing a mesh to the intrados and spraying concrete. In both cases, any shrinkage of the new concrete will

tend to make the old and the new material separate radially. Also these impervious rings prevent natural drainage between the stones or brick work of the arch so that special provision must be made to deal with water or under severe climatic conditions, such as inmountainous regions, with ice. Sprayed-on concrete will in any case change the appearance of an arch constructed of stone, brick or a combination of the two.

A more effective, but at times a more expensive, treatment is to remove the fill and cast the extra required thickness on the extrados of the arch. Usually, a full ring is cast but occasionally only the end quarters are strengthened to act as cantilevers and reduce the effective span of the arch. Normal concrete placing techniques are satisfactory. Replacement backfill may be with normal or lightweight concrete. The latter will reduce dead load on the foundations but may also reduce the factor of safety for stability of the substructure.

Another expedient which is satisfactory where the increase in load carrying capacity is relatively small, especially for small span bridges is to cast slab at road level to act as an auxiliary deck which spreads the wheel loads.

For cracks in arches, grouting with cement, at pressure 4 to 6 kg/sq.cm is sometimes quite effective, through care should be taken to see that pressure will not damage the surrounding masonry.

11.9. Repairs to Steel Structures

11.9.1. **Deck replacement of older steel bridges :** Many of the old bridges (usually truss or arch bridges) have either warped steel plates with a bituminous surfacing or a concrete deck. Due to insufficient waterproofing, the steel plates are often corroded.

Bridge decks can be replaced by new concrete decks or by new orthotropic steel decks, though these have not been used in India

so far. Usually, when a reduction in dead load or additional widening (adding cycle or pedestrian lanes) are necessary, replacement by an orthotropic steel deck is preferred. Bolting is the preferred method of connecting the new deck system to existing structural members.

Depending on the type of bridge and the load carrying capacity of its structural components, the new concrete deck is placed as a non-composite action with the stringer and/or cross beams) or as a totally composite element (i.e. in composite action with all main load carrying elements).

The use of light weight concrete is often preferred in such cases where reduction in dead load is an important factor. Sometimes to save weight, a type of steel grid decking is used where the grids can be either left open or filled with concrete.

11.9.2. **Strengthening of structural members :** Strengthening usually involves more conventional techniques such as installing new diaphragms to existing double compression members (increasing buckling strength), strengthening or replacement of diagonals. Plate girders may be strengthened by external prestressing cables, anchored and fixed on the web in the required parabolic curvature acting in a similar way as in prestressed concrete

Strengthening is sometimes concerned with compression failure and has involved the addition of stiffeners to flanges, webs, and diaphragms.

11.9.3. **Repair of cracks:** Cracks can be due to any one or a combination of the following reasons:

- Poor detailing so that high stress concentrations are present,
- Increased traffic loading beyond what was anticipated by the designer
- An unexpected secondary structural action,
- Inadequate analysis of complex stresses
- A large undetected fabrication flaw.

Crack repair methods depend on the root cause of crack

initiation. The structure and especially those components which influence the overall safety of the structure should be analysed.

11.9.4. Action to be taken when a crack is detected or suspected in welded steel bridge girders

(1) Location should be marked distinctly with paint. Ends of cracks should also be accurately marked to monitor crack propagation.

(2) Length and orientation of crack should be recorded. Sketch should be prepared indicating location and details of crack. If necessary photographs may be taken.

(3) If necessary, crack should be examined in detail using non-destructive inspection methods like dye penetrant, ultrasonic etc.

(4) If a crack is suspected at any location, paint film should be removed and detailed examination carried out using magnifying glass, dye penetrant inspection or ultrasonic inspection as necessary.

(5) If more identical details exist on the girder, they should also be inspected in detail.

(6) Crack should be fully documented in the bridge inspection register and action initiated for its early repair.

(7) The crack and girder should be kept under observations depending on the severity of crack and frequency of inspection suitably increased. If situation warrants, suitable speed restriction may be imposed.

(8) Significance and severity of crack should be studied for its effect on the load carrying capacity of the girder.

(9) Repair of retrofit scheme should be prepared after full investigation the cause of crack and implemented at the earliest.

Repairs can be made by techniques such as drilling holes at the crack tip (this should only be done in less sensitive locations), cutting out the cracked material and bolting plates in place, cutting out the crack and rewelding with a higher class weld (e.g. increasing the size and penetration of a fillet weld) strengthening the connection by introducing stiffening and by changing the structural action so that loads are supported in a way that prevents high stress range from developing.

11.9.5. **Underwater welding:** Arc welding has become an accepted procedure in underwater construction, salvage and repair operation. Underwater welds made on mild steel plate under test conditions carried out in developed countries, have consistently developed over 80 per cent of the tensile strength and 50 per cent of the ductility of similar welds made in air. The reduction in ductility is caused by hardening due to drastic quenching action of surrounding water. Structural quality welds have been produced by means of special equipment and procedures that create small, dry atmosphere in which the welding is performed. However, this process is expensive. Gas welding under water is not considered to be a feasible procedure.

A word of warning appears appropriate. Although arc welding and gas cutting are now common underwater techniques, electric shock is an ever present hazard. This hazard can only be minimized through the careful application of established procedures.

11.9.6. **Use of steel arch superposition scheme:** This can be used to strengthen old truss bridges. The strengthening scheme consists of superimposed arches, hangars and additional floor beams. The concept of combining a truss with an arch is by no means a new system. The idea is that a light arch can carry a significant load if properly supported laterally. In this case, the truss with its cross-beams provides the lateral support while the arch in combination with the hangars and additional floor beams provides the increased load carrying capacity. Additional floor beams and hangars are used for two reasons:

- The more uniform the load distribution, the more efficient the arch will be in carrying the load.
- The floor systems of many old truss bridges get deteriorated and are sometimes under - designed and unreliable.

The scheme of strengthening by a steel arch superposition is illustrated in Fig. 11.1.

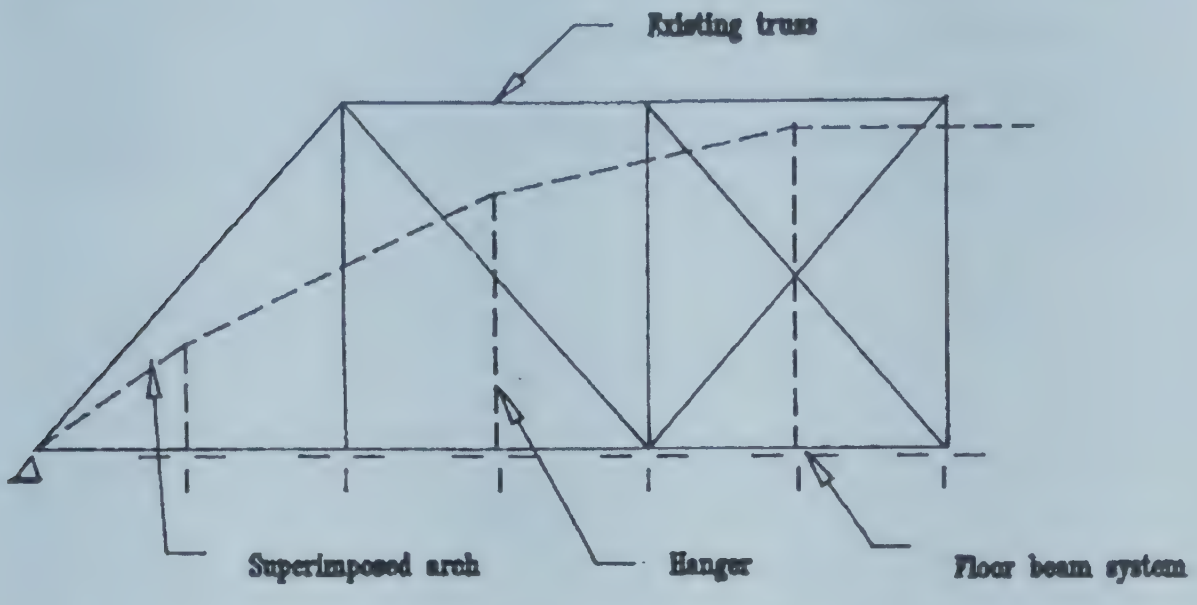


Fig. 11.1. Steel arch superimposition to strengthen old truss bridge

The thrust of the arch can be resisted by one of the following means:

- The abutments, provided they are adequate and in good condition, or they can readily be repaired or strengthened.
- A reinforced lower chord
- Superimposed cables or rods.
- Properly designed and detailed stringers or floor slab.

The arch superposition scheme can be considered as an overall strengthening measure. The load carrying capacity of the entire structure is upgraded, thus allowing the live load to be increased. There is no need for temporary shoring or jacking for the installation of the superpositioned elements. The increase in dead load can be expected to be in the order of approximately 15 to 20 per cent. The slender arch contributes only modest amounts of additional stiffness to the truss.

11.9.7. **Excessive vibrations:** These can be overcome by suitable structural alterations and increased damping for which a specialist in dynamic behaviour of structures may have to be consulted.

11.10. **Monitoring**: After the rehabilitation/strengthening of the structure is completed, it is essential that the bridge structure is kept under observation and its condition monitored regularly so as to ascertain its performance and the efficacy of the measures adopted. The monitoring may involve inspections at more frequent intervals, carrying out of certain laboratory and field tests as well as condition surveys and measurements to detect even small strains, movements, changes in deformation etc.

APPENDICES

APPENDIX - 1
(Cl. 2.2.5.1)

EMPIRICAL FORMULAE FOR CALCULATION OF DISCHARGE

1. Some of the popular empirical formulae for calculation of discharge are mentioned below:

1.1. Dicken's Formula

$$Q = CM^{3/4}$$

where Q = the peak run-off in cu.m/sec. And M is the catchment area in sq.km.

C = 11-14 where the annual rainfall is 60-120 cm;
14-19 in Madhya Pradesh;
32 in Western Ghats.

1.2. Ryve's Formula

$Q = CM^{2/3}$ The formula was devised for Chennai.

where Q is run-off in cu.m./sec., and
M is the catchment area in sq.km.

C = 6.8 for areas within 25 km of the coast
8.5 for areas between 25 and 160 km of the coast and
10.0 for limited areas near hills.

1.3. Inglish Formula

$$Q = \frac{125\,M}{\sqrt{M+10}}$$

where Q = maximum flood discharge in cu.m/sec.
M = the area of the catchment in sq. km.

The formula was devised for Bombay presidency.

1.4. These empirical formulae involve only one factor viz. area of the catchment and all the so many other factors that affect the run-off have to be taken care of in selecting an appropriate value of the coefficient. This is extreme simplification of the problem and cannot be expected to yield accurate results.

1.5. A correct value of C can only be derived for a given region from an extensive analytical study of the measured flood discharge vis-à-vis catchment area of streams in the region. Any value of C will be valid only for the region for which it has been determined in this way. Each basin has its own characteristics affecting run-off. Since actual flood records are seldom available the formula leaves much to the judgement of the Engineer-in-charge.

1.6. To assist routine computations Figs. 1 & 2 have been included in which curves have been plotted to represent the equation.

$Q =$ 10 M^n. Two curves one for each of the common values of n, viz.,2/3 and ¾ have been drawn.

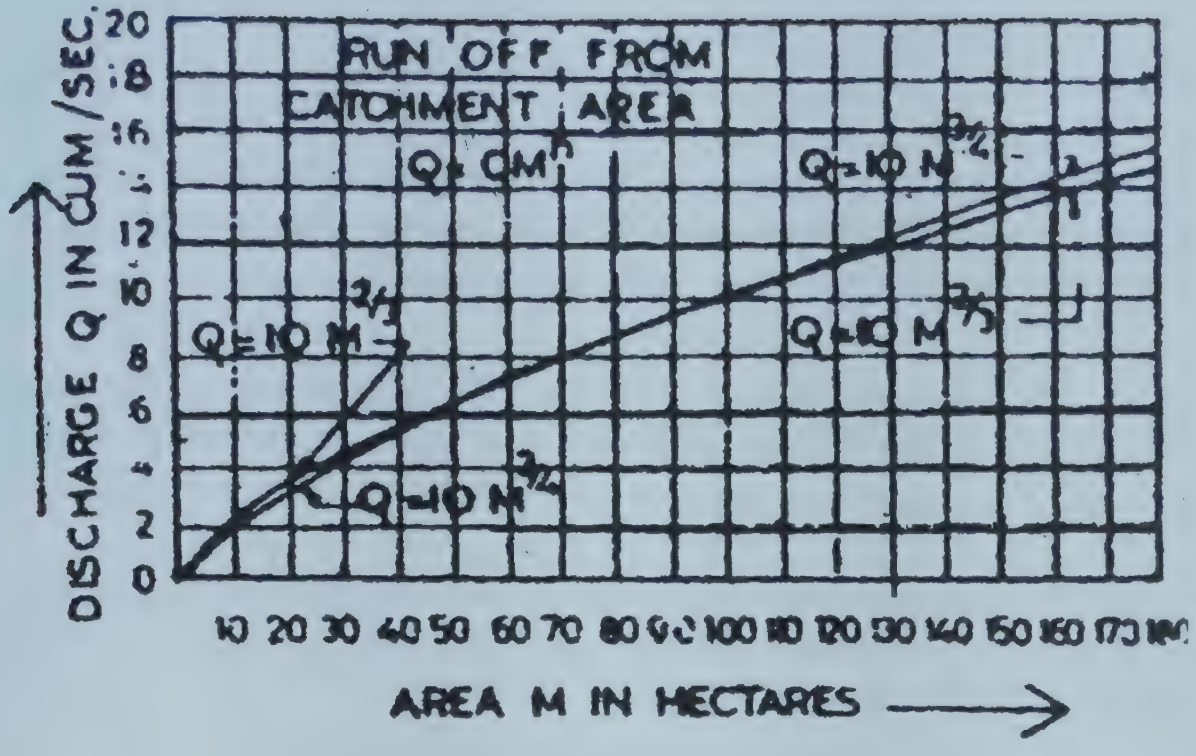

RUN OFF FROM
CATCHMENT AREA
Q = CM^n
Q=10 M^3/2
Q=10 M^2/3
Q=10 M^2/3
Q=10 M^2/3
DISCHARGE Q IN CUM/SEC.
AREA M IN HECTARES

Fig. 1

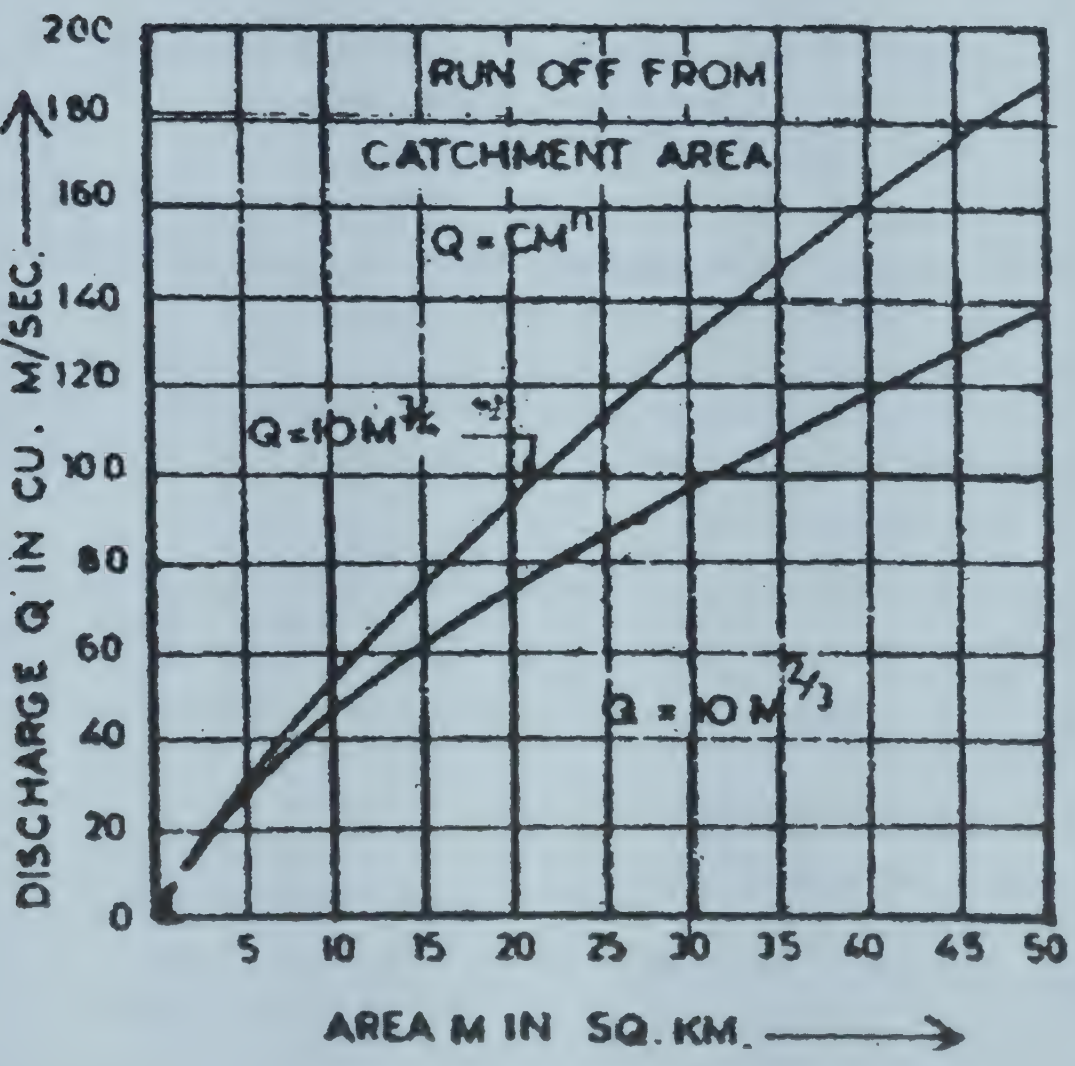

RUN OFF FROM
CATCHMENT AREA
Q = CM^n
Q=10M^3/2
Q = 10 M^2/3
DISCHARGE Q IN CU. M/SEC.
AREA M IN SQ. KM.

Fig. 2

APPENDIX – 2
(Cl. 2.2.5.1)

ESTIMATION OF FLOOD DISCHARGE BY THE AREA-VELOCITY METHOD WITH THE HELP OF HYDRAULIC CHARACTERISTICS OF THE CHANNELS

(1) **Calculation of Velocity**: Plot the probable scoured bed line. Measure the cross-sectional area A in sq.m. and wetted perimeter P in m. Then calculate the hydraulic mean depth R= A/P in m.

Next measure the bed slope S from the plotted longitudinal section of the stream. Velocity can then be calculated by using Manning Formula;

$$V = \frac{R^{2/3}\, S^{1/2}}{n}$$

where V = the velocity in m per sec., considered uniform throughout the cross-section
R = Hydraulic mean depth
S = the energy slope which may be taken equal to the bed slope measured over a reasonably long reach
n = the regosity coefficient

For values of n see Table 1 below. Judgement and experience are necessary in selecting a proper value of n for a given stream.

Table 1. Value of n

Surface (1)	Perfect (2)	Good (3)	Fair (4)	Bad (5)
Natural streams	(values of n)			
(1) Clean, straight bank, full stage, no rifts or deep pools.	0.025	0.0275	0.030	0.033
(2) Same as 1), but some weeds & stones	0.030	0.033	0.035	0.040
(3) Winding, some pools and shoals, clean	0.035	0.040	0.045	0.050

(1)	(2)	(3)	(4)	(5)
(4) Same as (3), lower stages, more ineffective slope and sections.	0.040	0.045	0.050	0.055
(5) Same as (3), some weeds and stones.	0.033	0.035	0.040	0.045
(6) Same as (4), stony sections	0.045	0.050	0.055	0.060
(7) Sluggish river reaches rather weedy or with very deep pools.	0.050	0.060	0.070	0.080
(8) Very weedy reaches.	0.075	0.100	0.125	0.150

(2) **Calculation of Discharge**

$$Q = A.V.$$
$$= \frac{A.R.^{2/3}\ S^{1/2}}{n}$$
$$= K\ S^{1/2} \quad \text{Where } K = \frac{A.R.^{2/3}}{n}$$

Now K is a function of the size, shape and roughness of the stream and is called its conveyance factor. Thus the discharge carrying capacity of a stream depends on its conveyance factor and slope.

APPENDIX – 3
(Cl. 2.2.5.1)

UNIT HYDROGRAPH METHOD

The unit hydrograph, frequently termed as the unit graph, is defined as the hydrograph of storm run-off at a given point in a river, resulting from an isolated rainfall of unit duration occurring uniformly over the catchment, and producing a unit run-off. The unit run-off adopted is 1 cm depth over a catchment area.

The term "Unit-rainfall duration" is the duration of rainfall excess resulting in the unit hydrograph. Usually, unit hydrographs are derived for specified unit durations, say, 6 hours, 12 hours, etc., and derived unit hydrographs for durations other than these are converted into unit hydrographs of the above unit durations. The duration selected should not exceed the period during which the storm is assumed to be approximately uniform in intensity over various parts of the catchment. A 6 hours unit duration is suitable and convenient for studies relating to catchments larger than 250 sq.km.

The unit hydrograph represents the integrated effects of all the basin constants, viz., drainage area, shape, stream pattern, channel capacities, stream and land slopes.

The derivation and application of the unit hydrograph is based on the following principles:

(1) All the characteristics of the catchment of a river are reflected in the shape of the hydrograph of run-off.

(2) At a given point, on a river, for all storms having the same duration of rainfall excess above this point and uniformly distributed with respect to time, the discharge ordinates of the hydrograph are proportional to the total volumes of storm run-off. This implies that rainfall excess of say 2 cm within the unit of duration will produce a run-off hydrograph having ordinates twice as great as those of the unit hydrograph. Also, if individual hydrographs are obtained from separate periods of uniform rainfall excess that may occur throughout a storm period, and these are properly arranged with

respect to time, the ordinates of the individual hydrographs can be added to give ordinates representing the total storm run-off hydrograph, for the entire storm period.

Three methods are generally available for giving unit hydrographs at any point in a river.

(i) By analysis of rainfall and run-off records for isolated unit storms;

(ii) By analysis of the run-off of compound hydrographs;

(iii) By computation of synthetic unit hydrographs, when sufficient rainfall and run-off data are not available.

The determination of design-flood, after the unit hydrograph has been derived, involves the following steps;

(a) Division of catchment into sub-areas, if necessary.
(b) Derivation of design-storm and its apportionment to sub-areas.
(c) Determination of minimum retention rate and calculation of rainfall excess of design-storm.
(d) Arrangement of design-storm.
(e) Application of rainfall excess to unit hydrographs for each sub-area.
(f) Routing of flood for each sub-area to the point of collection of the whole catchment.

A rational determination of critical design-storm for a catchment requires a comprehensive study of major storms recorded in the region and an evaluation of affects of local conditions upon rainfall rate. This is particularly necessary in the case of design-storms covering a large area of several thousand square kms.

In the case of areas less than a few thousand square kms., certain assumptions can be made regarding rainfall patterns and intensity variations, without being inconsistent with meteorological causes. They simplify design-storm estimation, but would entail a high degree of conservatism.

Flood estimation with the use of flood estimation reports brought out by CWC

Central Water Commission in association with RDSO of Ministry of Railways, Indian Meteorological Department and Ministry of Road Transport and Highways has carried out a research and brought out flood estimation reports for 24 sub-zone (as listed in table given in *Annexure – 1*) covering about 90% of geographic area of India. The reports provide a rational method of estimation of flood for small and medium catchments. A typical worked out example is given for reference at *Annexure – 2.*

ANNEXURE – 1 TO APPENDIX - 3

FLOOD ESTIMATION REPORTS BROUGHT OUT BY CENTRAL WATER COMMISSION (A METHOD BASED ON UNIT HYDROGRAPH PRINCIPLE)

UNDER LONG TERM PLAN

Sl.No.	Name of Sub-zone	Sub-zone No.
(1)	Chambal Sub-zone	1(b)
(2)	Betwa Sub-zone	1(c)
(3)	Sone sub-zone	1(d)
(4)	Upper Indo-Ganga Plains sub-zone	1(e)
(5)	Middle Ganga Plains Sub-zone	1(f)
(6)	Lower Gangetic Plains Sub-zone	1(g)
(7)	North Brahmaputra basin sub-zone	2(a)
(8)	South Brahmaputra basin sub-zone	2(b)
(9)	Mahi and Sabarmati sub-zone	3(a)
(10)	Lower Narmada and Tapi sub-zone	3(b)
(11)	Upper Narmada and Tapi sub-zone	3(c)
(12)	Mahanadi sub-zone	3(d)
(13)	Upper Godavari sub-zone	3(e)
(14)	Lower Godavari sub-zone	3(f)
(15)	Krishna & Pannar sub-zone	3(h)
(16)	Kaveri river sub-zone	3(i)
(17)	Eastern Coast sub-zones	4(a), 4(b) & 4(c)
(18)	Eastern Coast sub-zones	4a), 4(b) & 4(c)
(19)	Eastern Coast sub-zones	4(a), 4(b) & 4(c)
(20)	West Coast region sub-zones	5(a) & 5(b)
(21)	West Coast region sub-zones	5(a) & 5(b)
(22)	Luni sub-zone	1(a)
(23)	indravati sub-zone	3(g)
(24)	Western Himalayan sub-zone	7

ANNEXURE 2 TO APPENDIX-3

Procedure for estimation of design flood (Using typical example)

The flood estimation report for relevant sub-zone may be used for estimation of design flood (25 year, 50 year and 100 year) for ungauged or inadequately gauged catchments in the sub-zone. In order to elucidate the procedure, an illustrative example is given below with relevant details.

Illustrative example:

A typical example with reference to Bridge catchment (treated as ungauged) is worked out for illustrating the procedure to compute 50 year design flood. The particulars of the catchment under study are as under:-

(i)	Name & number of sub-zone	:	Mahi & Sabarmati Sub-zone – 3(a)
(ii)	Name of site (i.e. point of study)	:	Bridge No. 129
(iii)	Name of section	:	Dehod-Ratlam
(iv)	Name of tributary	:	Kali Nadi
(v)	Shape of the catchment	:	Oblong
(vi)	Site location	:	Latitude – 22^0 52' 00" Longitude – 74^0 22' 00"
vii)	Topography	:	Moderately steep slope

The procedure comprises of assessing A (area), L (Length of longest channel), S (Eq. Slope of channel) and then finding out Synthetic unit hydrograph ordinates by using these values and relationship derived by research study for the sub-zone concerned. Estimation of effective rainfall unit is done using 50 year 24 hour point rain fall values given in the report for design storm duration calculated earlier considering design loss rate. With unit hydrograph & 1 hr effective rainfall, 50 year flood is estimated considering design base flow.

The procedure is explained stepwise as follows:

Step 1: Preparation of Catchment Area Plan

The point of interest (i.e. bridge site in this case) was located on the Survey of India toposheet and chatchment boundary was marked using the contours along the ridge line and also from the spot levels in the plains. A catchment area plan Plate 1 showing the rivers, contours and spot levels was prepared.

Step 2: Determination of Physiographic Parameters

The following physiogrpahic parameters were determined from the catchment area plan i.e. Plate 1.

(i)	Area (A)	:	136.36 sq.km
(ii)	length of the longest stream(L)	:	33.50 km
(iii)	Length of the longest stream from a point opposite to centroid (C.G.) of the catchment area to the gauging site along the main stream (Lc)	:	17.00 km
(iv)	Equivalent stream slope (S)	:	3.26 m /km – For determining (S), observe reduced level of river bed at different points starting from bridge site. Following methods are adopted for computation of equivalent stream slope (S).

(a) By **Mathemcatical calculation:**

The computation of (S) with reference to Plate 1 is explained in the Table 1.

Table 1.

Sl. No.	Reduced distance starting from bridge site (km)	Reduced level of river bed (m)	Length of each segment, L_i (Km)	Height above the datum, D_i (m)	$D_{i-1} + D_i$ (m)	$L_i (D_{i-1} + D_i)$ (km x m)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	0	265.00 *	0	0	0	0
2	6.72	280.33	6.72	15.33	15.33	103.02
3.	14.40	300.65	7.68	35.65	50.98	391.53
4.	19.68	320.97	5.28	55.97	91.62	483.75
5.	24.48	340.57	4.80	75.57	131.54	631.39
6.	27.36	362.21	2.88	97.21	172.78	497.61
7.	29.76	380.44	2.40	115.44	212.65	510.36
8.	31.68	401.95	1.92	136.95	252.39	484.59
9.	32.64	418.26	0.96	153.26	290.21	278.60
10.	33.50	437.96	0.86	179.96	326.22	280.55
					Sum =	3661.40

* Datum i.e reduced level of river bed at point of study = 265.00m

Equivalent stream slope (S) $= \dfrac{\sum L_i (D_{i-1} + D_i)}{L^2} = \dfrac{3661.40}{(33.5)^2} = 3.26$ m/km

(b) **By Graphical Method:**

Draw a longitudinal section of the longest main stream from contours crossing the stream and the spot levels along the banks from the source to the point of study from the catchment plan shown in Plate 1. Draw a sloping line by trial on the L-Section line from the point of study such that the area above and below the L-Section line are equal. Then compute the slope of this line which gives the equivalent stream slope (S).

Step 3 Determination of 1-hour Synthetic Unitgraph Parameters:

The following relationships have been derived from the studies carried out by CWC & IMD for estimating the 1-hour unitgraph parameters for an ungauged catchment in the subzone 3(a). (Similar relationship for other sub-zones are also prepared and may be seen in reports of relevant sub-zones)

(i)	t_p	=	$0.433\ (L/\sqrt{S})^{0.704}$
(ii)	q_p	=	$1.161\ (t_p)^{-0.635}$
(iii)	W_{50}	=	$2.284(q_p)^{-1.00}$
(iv)	W_{75}	=	$1.331(q_p)^{-0.991}$
(v)	W_{R50}	=	$0.827(q_p)^{-1.023}$
(vi)	W_{R75}	=	$0.561\ (q_p)^{-1.037}$
(vii)	T_B	=	$8.375\ (t_p)^{0.512}$
(viii)	T_m	=	$t_p + t_r / 2$
(ix)	q_p	=	$q_p \times A$

where

t_p = Time from the center of unit rainfall duration to the peak of unit hydrograph in hours

q_p = Peak discharge of unit hydrograph per unit area in cumecs/sq.km

W_{50} = Width of unit hydrograph measured at 50 per cent max discharge ordinate (Q_p) in hours

W_{75} = Width of the unit hydrograph measured at 75 per cent max discharge ordinate (Q_p) in hours

W_{R50} = Width of the rising side of the unit hydrograph measured at 50 per cent of maximum discharge ordinate (Q_p) in hours

W_{R75} = Width of the rising side of the unit hydrograph measured at 75 per cent of maximum discharge ordinate (Q_p) in hours

T_b = Base width of unit hydrograph in hours

T_m = Time from the start of rise to the peak of unit hydrograph in hours

Q_p = Peak discharge of unit hydrograph in cumecs

L = Length of longest main stream along the river course in km

S = Equivalent stream slope in m/km

t_r = Unit rainfall duration adopted in a specific study in hours

A = Catchment area in sq.km.

The above equations were used to compute the unithydrograph parameters with the known values of *A, L and S* as under:-

(i) t_p	=	0.433 (33.50 / √ 3.26) $^{0.704}$	= 3.38 hrs, rounded off to 3.5 hours
(ii) q_p	=	1.161 (3.5) $^{-0.635}$	= 0.254 cum.ecs/sq.km
(iii) W_{50}	=	2.284 (0.254) $^{-1.00}$	= 4.36 hours
(iv) W_{75}	=	1.331 (0.254) $^{-0.991}$	= 2.52 hours
(v) WR_{50}	=	0.827 (0.254) $^{-1.023}$	= 1.60 hours
(vi) W_{R75}	=	0.561 (0.254) $^{-1.037}$	= 1.10 hours
(vii) T_B	=	8.375 (3.5)$^{0.512}$	= 15.90 hours say 16 hours
(viii) T_m	=	3.5 + 1 / 2	= 4.0 hours
(ix) Q_p	=	0.254 x 136.36	= 71.50 cumecs

Step 4:- Drawing of a synthetic unit hydrograph

Estimated parameters of unit hydrograph in Step 3 were plotted to scale on a graph paper as shown in Plate 2. The plotted points were joined to draw a synthetic hydrograph. The discharge indicated by unit hydrograph is calculated graphically by $\Sigma Q_i t_i$. This discharge is compared with theoretical discharge given by formula Q_{th} = A d / 0.36 x t. The above two values of discharge i.e. obtained by graphical and theoretical method are compared. In case graphical value is different from theoretical, the limb of synthetic unit hydrograph is adjusted to make it equal to theoretical value. The discharge ordinates *(Q_i)* of the unitgraph at $t_i = t_r$ = 1 hr interval were summed up and multiplied by t_r = 1 i.e. $\Sigma Q_i t_i$ = 378.8 cumec as shown in Plate 2. The theoretical volume of 1.00 cm direct runoff depth over the catchment was computed from the formula

$Q_{th} = A \times d / 0.36 \times t = 136.36 \times 1 / 0.36 \times 1 = 378.8$ cumecs

where A = catchment area in sq km

d = 1.0 cm depth

t_i = t_r (the unit duration of the UG) = 1.00 hr

Therefore, the sum of 1 hr U.G. = 378.8 cumecs. The sum of hourly ordinates ($\Sigma Q_i \times t_i$) of 1 hour. U.G. was compared with the sum of 1 hr U.G. obtained from the above formula.

In case the $\Sigma Q_i t_i$ for the unit hydrograph drawn is higher or lower than the volume worked out by the above formula, then the falling limb and / or rising limb may be suitably modified to get the correct volume under the hydrograph, taking care to get the smooth shape of the unit hydrograph.

Step 5: Estimation of Design Storm Duration

The design storm duration (T_D) = T_B = 16.00 hrs

Step 6: Estimation of Point Rainfall and Areal rainfall for storm duration

The site under study was located on Plate 3 of this Annexure showing 50-year 24-hr point rainfall. 50-yr 24-hr point rainfall = 32.0 cm. Conversion factor of 0.905 was read from Plate 4 for conversion of 50 yr 24-hr point rainfall to 50 yr 16-hr point rainfall since T_D = 16 hrs. 50 yr. 16 hr point rainfall thus worked out to be 32.00 x 0.905 = 28.96 cm. Areal reduction factor of 0.915 corresponding to a catchment area of 136.36 sq.km for T_D = 16 hrs was interpolated from Fig. 1 for conversion of point to areal rainfall. 50 year 16 hour areal rainfall = 28.96 x 0.915 = 26.50 cm.

Step 7: Time Distribution of Areal Rainfall

50-yr 16-hr areal rainfall = 26.50 cm was distributed with the distribution coefficients (Col.16 of Table 2) to get 1 hr rainfall increments as follows:

The hourly rainfall increments in col.(4) of the above table were obtained by subtracting the successive rainfall values from 1 hr onwards.

TABLE 2. TIME DISTRIBUTION COEFFICIENTS OF AREAL RAINFALL MAHI AND SABARMATI BASIN, SUBZONE-3(a)

Time in hours	Distribution	Coefficient for Design Storm Duration of 2-24 hrs.																						Time in hours
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
24																							1.00	24
23																						1.00	0.99	23
22																					1.00	0.99	0.98	22
21																				1.00	0.99	0.98	0.97	21
20																			1.00	0.98	0.98	0.97	0.95	20
19																		1.00	0.99	0.97	0.96	0.95	0.94	19
18																	1.00	0.98	0.98	0.96	0.95	0.94	0.93	18
17																1.00	0.99	0.97	0.97	0.95	0.93	0.92	0.90	17
16															1.00	0.99	0.97	0.96	0.95	0.93	0.90	0.89	0.87	16
15														1.00	0.99	0.98	0.96	0.94	0.93	0.90	0.88	0.86	0.84	15
14													1.00	0.98	0.98	0.97	0.94	0.91	0.89	0.88	0.85	0.84	0.82	14
13												1.00	0.98	0.97	0.96	0.94	0.93	0.88	0.86	0.84	0.83	0.80	0.78	13
12											1.00	0.98	0.97	0.96	0.94	0.93	0.90	0.85	0.84	0.82	0.80	0.78	0.77	12
11										1.00	0.99	0.96	0.94	0.92	0.91	0.89	0.87	0.82	0.80	0.78	0.77	0.76	0.74	11
10									1.00	0.99	0.98	0.94	0.92	0.91	0.88	0.86	0.85	0.78	0.76	0.75	0.74	0.73	0.71	10
9								1.00	0.99	0.97	0.96	0.91	0.89	0.87	0.86	0.83	0.82	0.76	0.74	0.72	0.71	0.69	0.67	9
8							1.00	0.98	0.97	0.96	0.93	0.87	0.86	0.83	0.82	0.80	0.76	0.72	0.70	0.68	0.67	0.65	0.63	8
7						1.00	0.98	0.96	0.95	0.92	0.88	0.83	0.82	0.79	0.77	0.76	0.73	0.66	0.65	0.63	0.62	0.61	0.59	7
6					1.00	0.98	0.96	0.93	0.90	0.86	0.84	0.79	0.76	0.75	0.73	0.70	0.68	0.63	0.61	0.59	0.58	0.57	0.55	6
5				1.00	0.97	0.96	0.92	0.86	0.84	0.82	0.79	0.72	0.70	0.68	0.66	0.64	0.62	0.56	0.55	0.53	0.52	0.51	0.50	5
4			1.00	0.96	0.93	0.87	0.84	0.82	0.77	0.75	0.73	0.66	0.64	0.62	0.60	0.58	0.57	0.50	0.48	0.47	0.46	0.43	0.42	4
3		1.00	0.95	0.93	0.87	0.80	0.74	0.73	0.71	0.67	0.65	0.58	0.56	0.55	0.53	0.52	0.51	0.41	0.40	0.39	0.38	0.36	0.35	3
2	1.00	0.94	0.88	0.82	0.76	0.68	0.66	0.60	0.58	0.57	0.52	0.47	0.45	0.43	0.41	0.40	0.39	0.33	0.32	0.31	0.30	0.28	0.27	2
1	0.87	0.75	0.68	0.61	0.54	0.50	0.43	0.42	0.39	0.37	0.36	0.32	0.30	0.29	0.28	0.24	0.22	0.22	0.21	0.18	0.16	0.14	0.13	1

Note : Hourly rainfall distribution coefficients are given in the vertical columns for various design storm durations from 2 to 24 hrs.

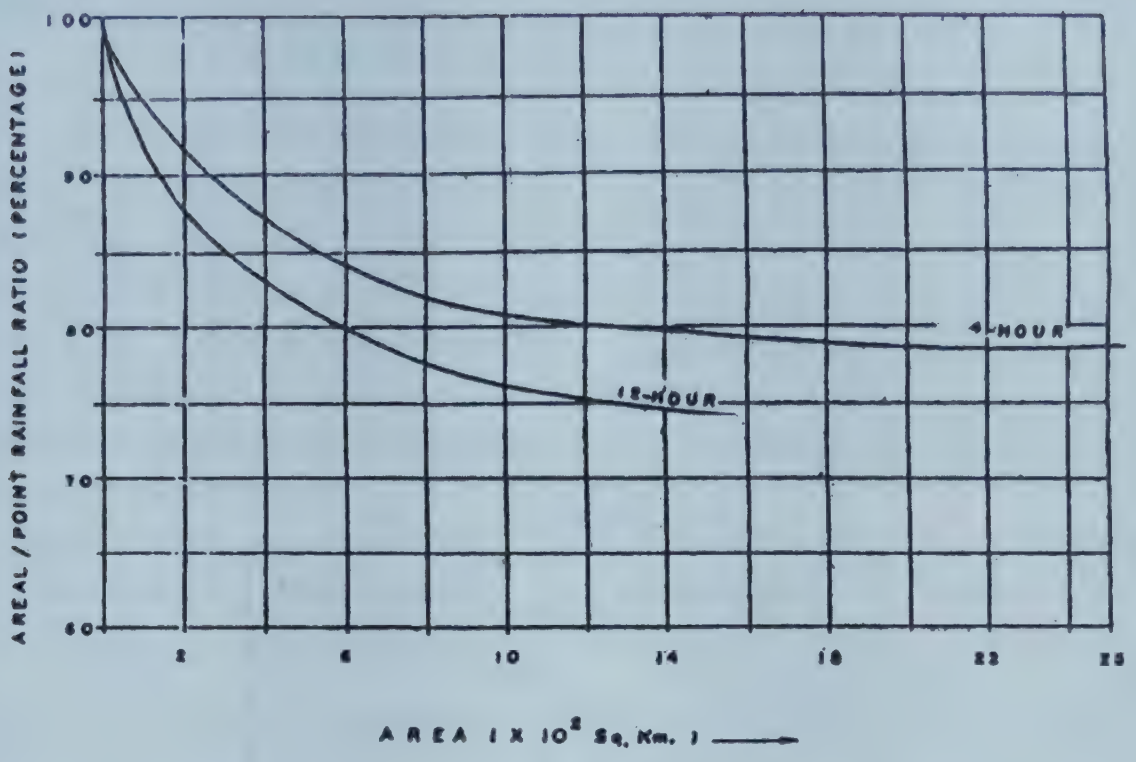


Fig. 1.

Step 8: Estimation of Effective Rainfall Units

Design loss rate of 0.45 cm/hr has been adopted for this sub-zone.

Table 3 the computation of 1-hr effective rainfall units in Col.(4) by substracting the design loss rate in Col.(3) from 1-hr rainfall increments in Col.(2).

Table 3

Durations (hrs)	Distribution Co-efficients (Col.16 of Table 2)	Storm rainfall = Rainfall x Distribution coefficient (cm)	1-hr rainfall increment (cm)
(1)	(2)	(3) = (2) x 26.50	(4)
1	0.28	7.42	7.42
2	0.41	10.86	3.44
3	0.53	14.04	3.18
4	0.60	15.90	1.86
5	0.66	17.49	1.59
6	0.73	19.34	1.85
7	0.77	20.40	1.06
8	0.82	21.73	1.33
9	0.86	22.79	1.06

(1)	(2)	(3) = (2) x 26.50	(4)
10	0.88	23.32	0.53
11	0.91	24.11	0.79
12	0.94	24.91	0.80
13	0.96	25.44	0.53
14	0.98	25.97	0.53
15	0.99	26.23	0.26
16	1.00	26.50	0.27

Table 4

Durations (hr)	1-hr rainfall (cm)	Design loss Rate (cm/hr)	1-hr effective rainfall (cm)
(1)	(2)	(3)	(4)
1	7.42	0.45	6.97
2	3.44	"	2.99
3	3.18	"	2.73
4	1.86	"	1.41
5	1.59	"	1.14
6	1.85	"	1.40
7	1.06	"	0.61
8	1.33	"	0.88
9	1.06	"	0.61
10	0.53	"	0.08
11	0.79	"	0.34
12	0.80	"	0.35
13	0.53	"	0.08
14	0.53	'	0.08
15	0.26	"	-
16	0.27	"	-

The column (2) in Table 4 is taken from col.(4) of Table 3.

Step-9: Estimation of Base Flow

The design base flow for this sub-zone is recommended to be computed by the following formulae:

$q_b = 0.109/A^{0.126}$

$q_b = 0.109 / (136.36)^{0.126} = 0.059$ cumec/sqkm

Total Base Flow = 136.36 x 0.059 = 8.04 cumecs

Step 10: Estimation of 50-yr Flood (Peak Only)

For the estimation of the peak discharge the effective rainfall units were re-arranged against the unitgraph ordinates such that the maximum effective rainfall was placed against the maximum U.G. ordinate, (obtained from the UG diagram plotted after Step 4), the next lower value of rainfall effective against the next lower value of U.G. ordinate and so on as shown in Cols.(2) and (3) in the following table. Summation of the product of U.G. ordinate and rainfall gives the total direct runoff as in Table 5 below:

Table 5

Time	U.G. Ordinate (cumecs)	1-hr Effective Rainfall (cm)	Direct Runoff (cumecs)
(1)	(2)	(3)	(4)
1	9.00	0.34	3.06
2	25.00	1.14	29.07
3	58.00	2.73	158.34
4	71.50	6.97	498.35
5	61.00	2.99	182.39
6	44.50	1.41	62.74
7	32.70	1.40	45.78
8	24.50	0.88	21.56
9	18.00	0.61	10.98
10	12.70	0.61	7.75
11	9.50	0.35	3.32
12	5.70	0.08	0.46
13	3.50	0.08	0.28
14	2.00	0.08	0.16
			1024.24
			Base Flow 8.04
			50-yr Flood Peak 1032.28 cumecs

NOTES —

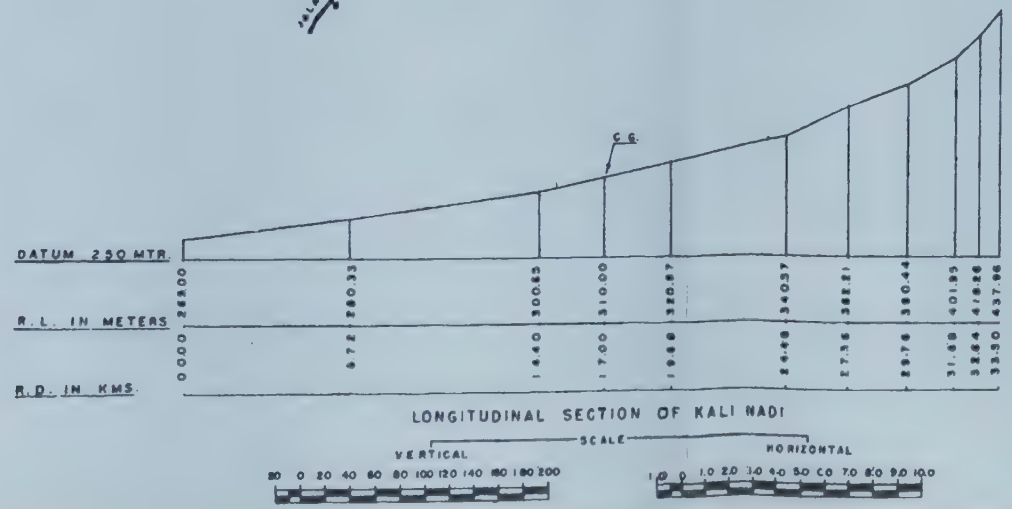
1. ALL LEVELS CORRESPOND TO G.T.S. DATUM
2. H. F. L. AT BRIDGE SITE

REFERENCES —

1.	CATCHMENT BOUNDARY	
2.	RAILWAY LINE	
3.	RIVER AND IT'S TRIBUTARIES	
4	ROADS	
5	RAINGAUGE STATIONS	
6	CONTOURS	300 320
7	TOPOSHEET NO.	46 J/5, J/6
8	CENTRE OF GRAVITY	⊙

DETAIL OF CATCHMENT AREA

1	AREA OF THE CATCHMENT	136.36 Sq.Km.
2	SHAPE OF CATCHMENT	ELONGATED
3	L.	33.50 Km.
4	Lc.	17.00 Km.
5	Wc.	7.95 Km.
6	SLOPE (EQUILIBRIUM)	3.283 Mt/Km.
7	D.	3.085 Km./Sq.Km



LONGITUDINAL SECTION OF KALI NADI

SCALE

VERTICAL: 20 0 20 40 60 80 100 120 140 160 180 200

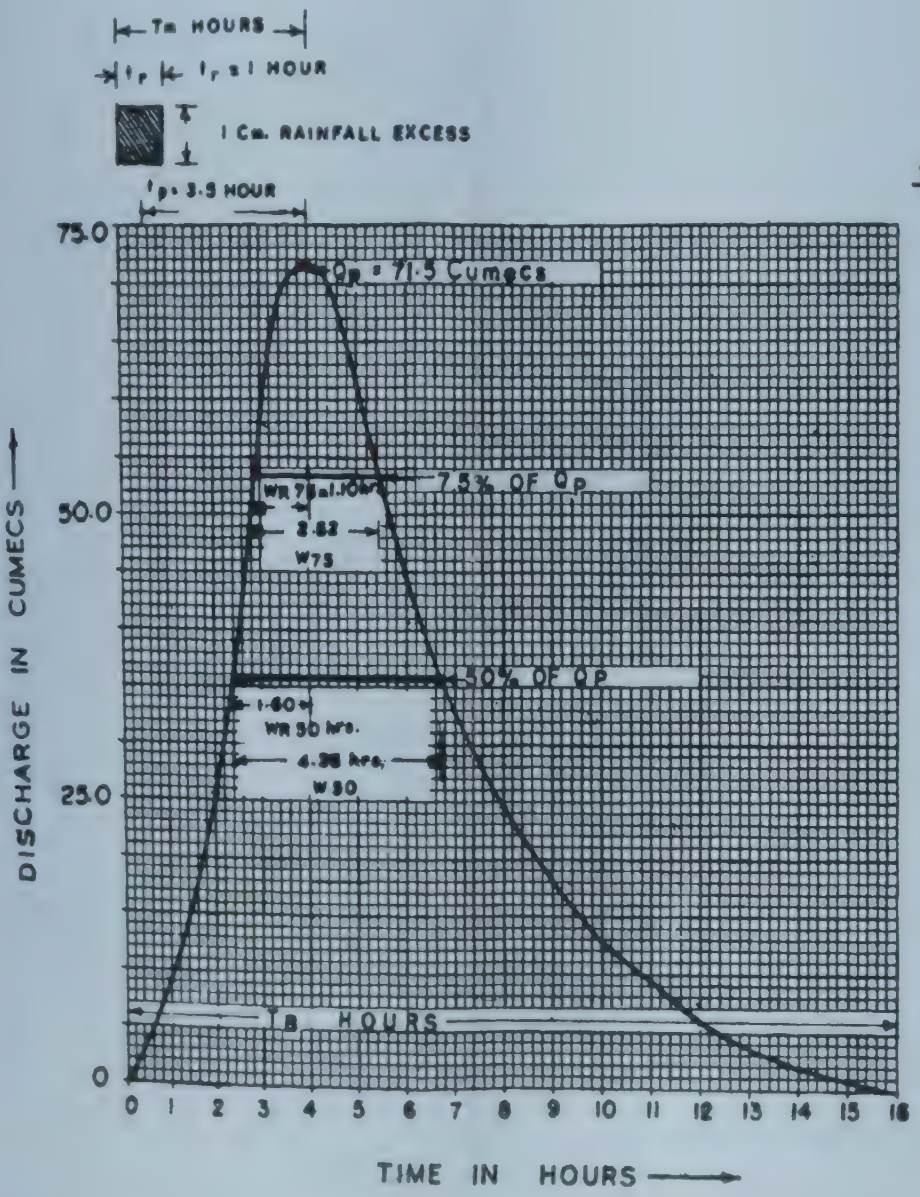
HORIZONTAL: 1.0 0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

NOTE:-
CONTOURS (IN METRES) SHOWN ON THE PLAN HAVE BEEN ROUNDED UP AFTER CONVERSION FROM FEET TO METRE
LONGITUDINAL SECTION IS DRAWN WITH THE ACTUAL VALUES OF CONTOUR IN METRES

SI. NO.	NAME OF R.G. STATION	LOCATION		STATION WTS. 1981 - 1984
		LONG.	LATI.	
1	KATLA	74°-22'-55"	22°-47'-40"	0 4 0 8
2	AGAWADA	74°-22'-35"	22°-45'-00"	0.4 9 5
3	BR. SITE	74°-22'-27"	22°-52'-00"	0.0 9 7

SCALE

0.5 0 1.0 2.0 3.0 4.0 5.0



SYNTHETIC U.G. PARAMETERS

C.A.	=	136.36 SQ.KM.
t_p	=	3.5 nrs.
T_B	=	16.0 hrs.
Q_p	=	71.5 Cumecs.
W_{50}	=	4.36 hrs.
W_{75}	=	2.52 hrs.
W_{R50}	=	1.60 hrs.
W_{R75}	=	1.10 hrs.
q_p	=	0.524 Cumecs/Sq. Km.
$\frac{L}{\sqrt{S}}$	=	19.0
Tm	=	4.0 hrs.
d	=	1.00 Cm.

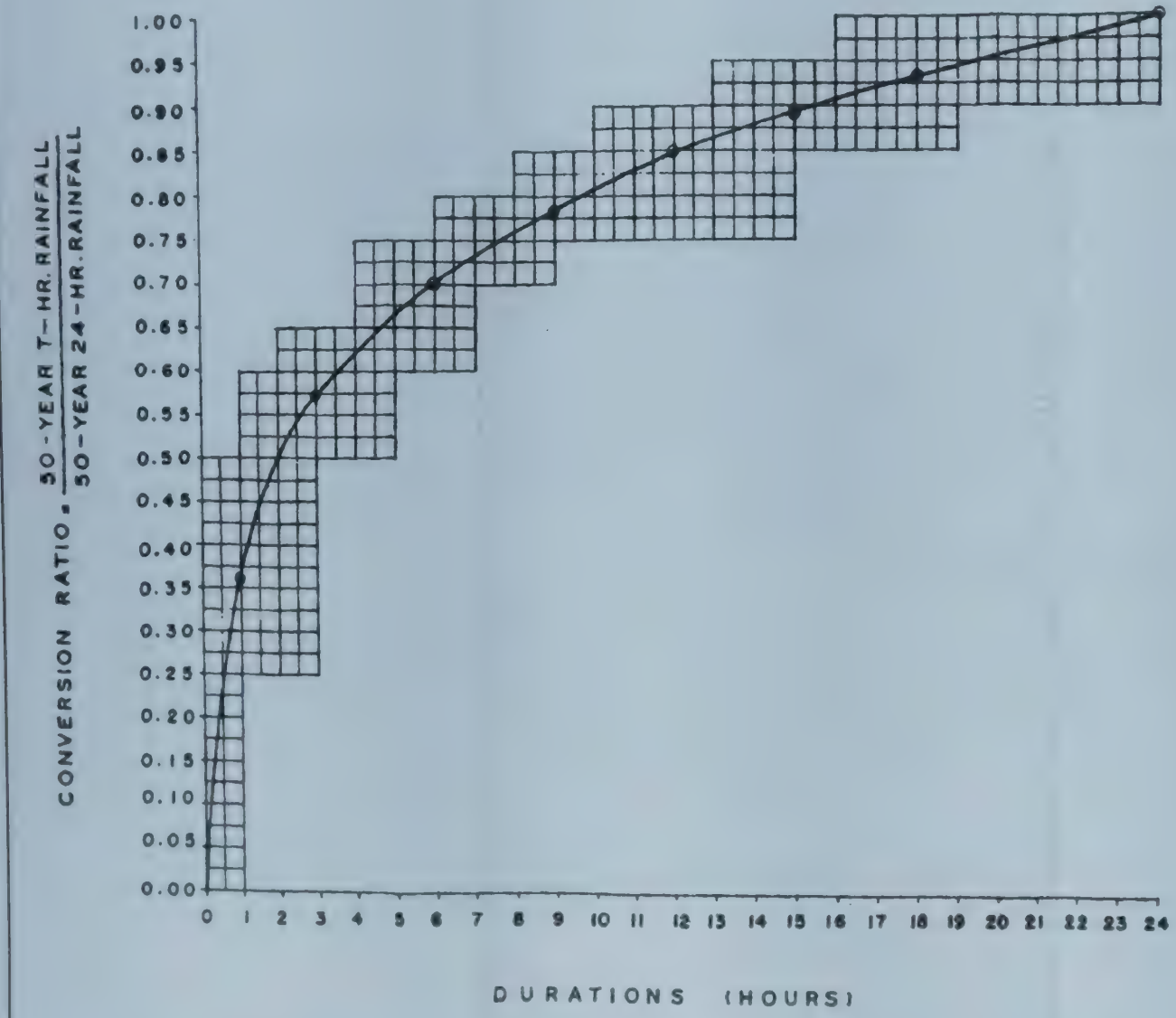
$$\Sigma Q_i = \frac{A \times d}{t_r \times 0.36}$$

$$= \frac{136.36 \times 1.00}{1.00 \times 0.36}$$

= 378.80 Cumecs.

TIME IN (HOURS)	1-HOUR SYNTHETIC U.G. ORDINATES (CUMECS)
0	0
1	9.00
2	25.50
3	58.00
4	71.50
5	61.00
6	44.50
7	32.70
8	24.50
9	18.00
10	12.70
11	9.50
12	5.70
13	3.50
14	1.90
15	0.80
16	0
TOTAL	378.80

SUB ZONE 1-a
SUB ZONE 3-b
SUB ZONE
N
UDAIPUR CITY
DEOLIA
HIMAT NAGAR
GANDHINAGAR
AHMADABAD
DOHAD
VADODARA
JAMNAGAR
RAJKOT
OKHA
DWARKA
PORBANDAR
VERAVAL
KHAMBHAT
GULF OF KUTCH
GULF OF CAMBAY
ARABIAN SEA
LEGEND.
1 SUB ZONE BOUNDARY
2 RIVERS
3 TOWNS
4 ISOPLUVIALS
5 BRIDGE SITES
NOTE:- THE TERRITORIAL WATER OF INDIA EXTEND INTO THE SEA TO A DISTANCE OF TWELVE NAUTICAL MILES MEASURED FROM THE APPROPRIATE BASE LINE
NOTE:- RESPONSIBILITY FOR THE CORRECTNESS OF INTERNAL DETAILS LIES WITH THE PUBLISHER.
BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSION OF THE SURVEYOR GENERAL OF INDIA.
GOVERNMENT OF INDIA COPYRIGHT 1986.



RATIOS OF 24-HR. POINT RAINFALL TO SHORT DURATION RAINFALL.

DURATION (HRS.)	RATIO
1	0.360
2	0.505
3	0.570
4	0.620
5	0.665
6	0.700
7	0.730
8	0.760
9	0.780
10	0.805
11	0.825
12	0.850
13	0.860
14	0.875
15	0.890
16	0.905
17	0.920
18	0.930
19	0.945
20	0.960
21	0.970
22	0.980
23	0.990
24	1.000

APPENDIX - 4
(Cl. 2.2.5.1)

RATIONAL FORMULAE FOR PEAK RUN OFF

$$Q = 0.028\ P\ f\ A\ I_o\ (2\ /(Tc+1))$$

where Q = max. run-off in cu.m./sec.

A = area of the catchment in hectare

Io = Heaviest intensity of rainfall in one hour in the catchment in cm per hour which may be taken as 13cm for western ghats and the north eastern states and 10cm in the rest of the country.

P = percentage coefficient of run-off for the catchment characteristics (ref. Table 1 below).

f = a factor considering the likely spread of the storm in relation to the area of the catchment (Ref. Fig. A-4-1).

Tc = time of concentration of flood for the particular catchment = $(0.87 * L3/H)^{0.385}$

where L = distance of the critical point to the bridge along the river

H = fall in level from the critical point to the bridge in km.

Table 1 (Value of P)

Steep Bore rock/City pavements	=	0.90
Steep rock, wooded	=	0.80
Plateaus, lightly covered	=	0.70
Clayey Soils, Stiff Bare	=	0.60
Clayey Soils, lightly covered.	=	0.50
Loam, lightly cultivated/vegetated	=	0.40
Loam, largely cultivated	=	0.30
Sandy soil, lightly vegetated	=	0.20
Sandy soil, thickly vegetated heavy brush	=	0.10

Catchment area in hectares Fig. 1 (f versus catchment area)

Appendices

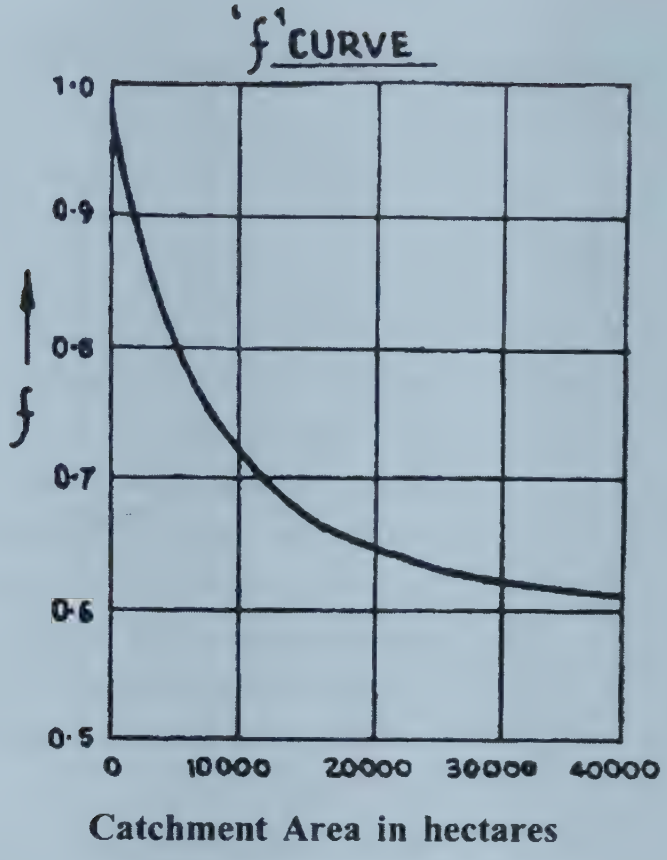
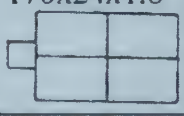
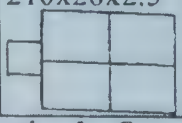


Fig. 1.

APPENDIX - 5
(Cl. 2.28)

CLASSIFICATION OF INLAND WATERWAYS IN INDIA WITH MINIMUM CLEARANCE FOR CROSS STRUCTURES

Class of water-way	Tonnage (DWT) of SPV (T)	Barge Units			Minimum Dimensions of navigational channel in lean season					Minimum Clearances for cross structures		
					Rivers		Canals		Radius at bend	Horizontal Clearance between piers		Vertical clearance
		Dimension of single barge (LxBxD) (M)	Dimension of barge units (LxBxD) (M)	Tonnage of barge units (DWT) (T)	Depth * (M)	Bottom width (M)	Depth * (M)	Bottom width (M)	(M)	Rivers (M)	Canals (M)	** (M)
I	100	32x5x1.0	80x5x1.0	200	1.2	30	1.5	20	300	30	20	4.0
II	300	45x8x1.2	110x8x1.2	600	1.4	40	1.8	30	500	40	30	5.0
III	500	58x9x1.5	141x9x1.5	1000	1.7	50	2.2	40	700	50	40	7.0
IV	1000	70x12x1.8	170x12x1.8	2000	2.0	50	2.5	50	800	50	50	10.0
IV(A)	1000	70x12x1.8	170x24x1.8 	4000	2.0	80	-	-	800	80	-	10.0
V	2000	86x14x2.5	210x14x2.5	4000	2.75	60	3.5	60	900	60	60	10.0
V(A)	2000	86x14x2.5	210x28x2.5 	8000	2.75	100	-	-	900	100	-	10.0

SPV: Self Propelled Vessel L: Overall Length B: Beam Width D: Loaded Draft

* Minimum depth of channel should be available for 95% of the year

** This vertical clearance should be available in atleast central 75% portion of each of the spans in entire width of the waterway during lean season.

Reference level for vertical clearance in different types of channels is given below.

(A) For rivers, over navigational hgih flood level (NHFL), which is the highest flood level. At a frequency of 5% in any year over a period of last twenty years.

(B) For tidal canals, over the highest high water level.

(C) For other canals, over designed full supply level.

APPENDIX - 6
[Cl 2.2.11.6 (xi)]

LIST OF STANDARD PLANS FOR HIGHWAY BRIDGES PREPARED BY THE MINISTRY OF SURFACE TRANSPORT (ROADS WING), GOVERNMENT OF INDIA REQUIRING REVISION

(A) Standard Plans for 3.0m to 10.0m span Reinforced Cement Concrete Solid Slab Superstructure with and without footpaths for Highways, 1991.

(B) Standard Plans for Highway Bridges RCC T-Beam & Slab Superstructure – Span from 10m to 24m with 12m width, 1991.

(C) Standard Plans for Highway Bridges – PSC Girder and RC Slab Composite Superstructure for 30m Span with and without footpaths, 35m Span with Footpaths and 40m Span without Footpaths, 1991.

(D) Standard Drawings for Road Bridges – R.C.C. Solid Slab Superstructure (15^0 & 30^0) skew Span 4.0m to 10.0m (with and without Footpaths), 1992.

(E) Standard Plans for Highway Bridges & RCC Slab Type Superstructure – Vol.II, Prestressed Concrete Beams with one end Prestressed for 30m Span with and without Footpath, 35m Span with Footpath and 40m Span without Footpath, 1999.

Additional Drawing

(i) Voided RCC slab for 10m to 20m span (at increment of 1m with / without footpaths)

(ii) Voided PSC slab 15m to 24m (3m interval with or without footpaths)

(iii) PSC girder and RCC slab composite superstructure for 35m span without footpath & 40m span with footpath

(iv) RCC solid slab superstructure (20^0, 25^0, & 35^0 skew) span 4 to 10m (at 1 m interval with and without footpath)

(v) Box girder superstructure for span 35m, 40m & 95m (with and without footpath)

(A) Standard Plans for 3.0m to 10.0m span Reinforced Cement Concrete Solid Slab Superstructure with and without Footpaths for Highways, 1991.

DRAWING DESCRIPTION	DRAWING NO.
A. General	
General Notes	SD/101
General Arrangement	SD/102
Miscellaneous details	SD/103 & SD/104
Details of R.C.C. railings (Without Footpaths)	SD/105
Details of R.C.C. Railings (With Footpaths)	SD/106

B. Reinforcement Details & Quantities for Slabs Without Footpaths

Effective span	3.0m	SD/107
"	4.0m	SD/108
"	5.0m	SD/109
"	6.0m	SD/110
"	7.0m	SD/111
"	8.0m	SD/112
"	9.0m	SD/113
"	10.0m	SD/114

C. Reinforcement Details & Quantities for Slabs with Footpaths

Effective span	3.0m	SD/115
"	4.0m	SD/116
"	5.0m	SD/117

"	6.0m	SD/118
"	7.0m	SD/119
"	8.0m	SD/120
"	9.0m	SD/121
"	10.0m	SD/122

(B) Standard Plans for Highway Bridges RCC T-Beam & Slab Superstructure - Span from 10m to 24m with 12m width, 1991.

(DRAWINGS)

		Drawing No.
(A)	**Notes**	
(1)	General notes	SD/200
(B)	**R.C.C. T-beam bridges 24.0 M span**	
(1)	General arrangement (for bridges without footpaths)	SD/210
(2)	General arrangment (for bridges with footpaths)	SD/211
(3)	Details of deck slab (for bridges without footpaths)	SD/212
(4)	Details of deck slab (for bridges with footpaths)	SD/213
(5)	Details of longitudinal girders	SD/214
(6)	Details of cross girders	SD/215
(7)	Schedule of reinforcement (for bridges without footpaths)	SD/216 Sh-1
(8)	Schedule of reinforcement (for bridges without footpaths)	SD/216 Sh-2
(9)	Schedule of reinforcement (for bridges with footpaths)	SD/217 Sh-1
(10)	Schedule of reinforcement (for bridges with footpaths)	SD/217 Sh-2

(C) RCC T.Beam bridges – 21.0 M Span

(1)	General arrangement (for bridges without footpaths)	SD/220
(2)	General arrangement (for bridges with footpaths)	SD/221
(3)	Details of deck slab (for bridges without footpaths)	SD/222
(4)	Details of deck slab (for bridges with footpaths)	SD/223
(5)	Details of longitudinal girders	SD/224
(6)	Details of cross girders	SD/225
(7)	Schedule of reinforcement (for bridges without footpaths)	SD/226 Sh-1
(8)	Schedule of reinforcement (for bridges without footpaths)	SD/226 Sh-2
(9)	Schedule of reinforcement (for bridges with footpaths)	SD/227 Sh-1
(10)	Schedule of reinforcement (for bridges with footpaths)	SD/227 Sh-2

(D) RCC T. Beam bridges – 18.0 M Span

(1)	General arrangement (for bridges without footpaths)	SD/230
(2)	General arrangement (for bridges with footpaths)	SD/231
(3)	Details of deck slab (for bridges without footpaths)	SD/232
(4)	Details of deck slab (for bridges with footpaths)	SD/233
(5)	Details of longitudinal girders	SD/234
(6)	Details of cross girders	SD/235
(7)	Schedule of reinforcement (for bridges without footpaths)	SD/236 Sh-1
(8)	Schedule of reinforcement (for bridges without footpaths)	SD/236 Sh-2
(9)	Schedule of reinforcement (for bridges with footpaths)	SD/237 Sh-1
(10)	Schedule of reinforcement (for bridges with footpaths)	SD/237 Sh-2

(E) RCC T. Beam bridges – 16.0 M Span

(1)	General arrangement (for bridges without footpaths)	SD/240
(2)	General arrangement (for bridges with footpaths)	SD/241
(3)	Details of deck slab (for bridges without footpaths)	SD/242
(4)	Details of deck slab (for bridges with footpaths)	SD/243
(5)	Details of longitudinal girders	SD/244
(6)	Details of cross girders	SD/245
(7)	Schedule of reinforcement (for bridges without footpaths)	SD/246 Sh-1
(8)	Schedule of reinforcement (for bridges without footpaths)	SD/246 Sh-2
(9)	Schedule of reinforcement (for bridges with footpaths)	SD/247 Sh-1
(10)	Schedule of reinforcement (for bridges with footpaths)	SD/247 Sh-2

(F) RCC T-beam bridges - 14.0 M Span

(1)	General arrangement (for bridges without footpaths)	SD/250
(2)	General arrangement (for bridges with footpaths)	SD/251
(3)	Details of deck slab (for bridges without footpaths)	SD/252
(4)	Details of deck slab (for bridges with footpaths)	SD/253
(5)	Details of longitudinal girders	SD/254
(6)	Details of cross girders	SD/255
(7)	Schedule of reinforcement (for bridges without footpaths)	SD/256 Sh-1
(8)	Schedule of reinforcement (for bridges without footpaths)	SD/256 Sh-2
(9)	Schedule of reinforcement (for bridges with footpaths)	SD/257 Sh- 1
(10)	Schedule of reinforcement (for bridges with footpaths)	SD/257 Sh-2

(G) RCC T-beam bridges - 12..0 M Span

(1)	General arrangement (for bridges without footpaths)	SD/260
(2)	General arrangement (for bridges with footpaths)	SD/261
(3)	Details of deck slab (for bridges without footpaths)	SD/262
(4)	Details of deck slab (for bridges with footpaths)	SD/263
(5)	Details of longitudinal girders	SD/264
(6)	Details of cross girders	SD/265
(7)	Schedule of reinforcement (for bridges without footpaths)	SD/266 Sh-1
(8)	Schedule of reinforcement (for bridges without footpaths)	SD/266 Sh-2
(9)	Schedule of reinforcement (for bridges with footpaths)	SD/267Sh-1
(10)	Schedule of reinforcement (for bridges with footpaths)	SD/267 Sh-2

(H) RCC T-beam bridges - 10.0 M Span

(1)	General arrangement (for bridges without footpaths)	SD/270
(2)	General arrangement (for bridges with footpaths)	SD/271
(3)	Details of deck slab (for bridges without footpaths)	SD/272
(4)	Details of deck slab (for bridges with footpaths)	SD/273
(5)	Details of longitudinal girders	SD/274
(6)	Details of cross girders	SD/275
(7)	Schedule of reinforcement (for bridges without footpaths)	SD/276 Sh-1
(8)	Schedule of reinforcement (for bridges without footpaths)	SD/276 Sh-2
(9)	Schedule of reinforcement (for bridges with footpaths)	SD/277 Sh-1
(10)	Schedule of reinforcement (for bridges with footpaths)	SD/277 Sh-2

(I) Railings

(1)	Details of RCC railing (for bridges without Footpaths)	SD/201
(2)	Details of RCC railing (for bridges with Footpaths)	SD/202

(J) Bearings

(1)	Details of elastomeric bearing	SD/203
(2)	Details of Rocker bearing	SD/204 Sh- 1
(3)	Details of Roller bearing	SD/204 Sh-2
(4)	Details of seismic attachment	SD/204 Sh-3

(K) Miscellaneous

(1)	Details of miscellaneous items	SD/205

(C) Standard Plans for Highway Bridges – PSC Girder and RC Slab Composite Superstructure for 30m Span with and without Footpaths, 35 m Span with Footpaths and 40 m Span without Footpaths, 1991

DRAWING NO. TITLE

(1) General

SD/301 (Sheets 1 & 2)	General Notes
SD/302	General Arrangement
SD/303	Details of Wearing Coat and Drainage System
SD/304	Details of RCC Railing for Superstructure without Footpaths
SD/305	Details of RCC Railing for Superstructure with Footpaths
SD/306 (Sheets 1, 2 & 3)	Details of Bearings

(2) 30.0m Span without footpaths

SD/311	Dimensions & Anchorage Details
SD/312	Prestressing Cables
SD/313	Reinforcement in Deck Slab and Kerb
SD/314	Reinforcement in Main Girders
SD/315	Reinforcement in End Cross Girders
SD/316	Reinforcement in Intermediate Cross Girders
SD/317	Schedule of Reinforcement

(Sheets 1, 2 & 3)

(3) 30.0m span with footpaths

SD/321	Dimensions & Anchorage Details
SD/322	Prestressing Cables
SD/323	Reinforcement in Deck Slab, Kerb and Footpath
SD/324	Reinforcement in Main Girders
SD/325	Reinforcement in End Cross Girders
SD/326	Reinforcement in Intermediate Cross Girders
SD/327	Schedule of Reinforcement

(Sheets 1, 2 & 3)

(4) 35.0m span with footpaths

SD/331	Dimensions & Anchorage Details
SD/332	Prestressing Cables
SD/333	Reinforcement in Deck Slab, Kerb and Footpath
SD/334	Reinforcement in Main Girders
SD/335	Reinforcement in End Gross Girders
SD/336	Reinforcement in Intermediate Cross Girders
SD/337	Schedule of Reinforcement

(Sheets 1, 2 & 3)

(5) 40.0m span without footpaths

SD/341	Dimensions & Anchorage details
SD/342	Prestressing Cables
SD/343	Reinforcement in Deck Slab and Kerb

SD/344	Reinforcement in Main Girders
SD/345	Reinforcement in End Cross Girders
SD/346	Reinforcement in Intermediate Cross Girders
SD/347	Schedule of Reinforcement

(Sheets 1, 2 & 3)

(D) Standard Drawings for Road Bridges – R.C.C. Solid Slab Superstructure (15⁰& 30⁰ skew) Span 4.0 m to 10.0 m (with and without Footpaths), 1992.

	Drawing description	**DRG.NO.**
(A)	General Notes	SD/151
	General Arrangement	SD/152-SD/153
	Miscellaneous details	SD/156 – SD/158
	Details of R.C.C. Railings (without footpaths)	SD/159
	Details of R.C.C. Railings (with footpaths)	SD/160

(B) R.C.C. Solid Slab Superstructure (15° skew) without footpaths

Effective span	4.0m	SD/161
"	6.0m	SD/162
"	8.0m	SD/163
"	10.0m	SD/164

(C) R.C.C. Solid Slab Superstructure (15° skew) with footpaths

Effective span	4.0m	SD/165
"	6.0m	SD/166
"	8.0m	SD/167
"	10.0m	SD/168

(D) R.C.C. Solid Slab Superstructure (30° skew) without footpaths

Effective span	4.0m	SD/169
"	6.0m	SD/170
"	8.0m	SD/171
"	10.0 m	SD/172

(E) R.C.C. Solid Slab Superstructure (30° skew) with footpaths

Effective span	4.0m	SD/173
"	6.0m	SD/174
"	8.0m	SD/175
"	10.0m	SD/176

(E) Standard Plans for Highway Bridges & RCC Slab Type Superstructure Bridges – Vol.II, Prestressed Concrete Beams with one end Prestressed for 30 m Span with and without Footpath, 35 m Span with Footpath and 40 m Span without Footpath, 1999.

PART – I STRAND SYSTEM

	DRAWING NO.	**TITLE**
1.	General	
	(i) SD/401 (Sheets 1 & 2)	General Notes
	(ii) Bill of Quantities	
2.	30m without footpath SD/412	Prestressing Cables
3.	30m with footpath SD/422	Prestressing Cables
4.	35m with footpath SD/432	Prestressing Cables
5.	40m without footpath SD/442	Prestressing Cables

PART – 2 MULTI WIRE SYSTEM

	DRAWING NO.	*TITLE*
1.	General	
(i)	SD/501 (Sheets 1 & 2)	General Notes
2.	30m without footpath	
	SD/511	Dimensions and Anchorage Details
	SD/512	Prestressing Cables
3.	30m with footpath	
	SD/521	Dimensions and Anchorage Details
	SD/522	Prestressing Cables
4.	35m with footpath	
	SD/531	Dimensions and Anchorage Details
	SD/532	Prestressing Cables
	SD/535	Reinforcement in End Cross Girders
5.	40m without footpath	
	SD/541	Dimensions and Anchorage Details
	SD/542	Prestressing Cables
	SD/545	Reinforcement in End Cross Girders

APPENDIX – 7
(Cl.2.2.14.2)

GUIDELINES FOR PLANNING AND EXECUTION OF BRIDGES ACROSS IRRIGATION CANALS

(1) In case of bridges proposed for construction across irrigation channels, the assured closure periods and the periods during which these channels are expected to run at low supply levels should be determined and got authenticated by the Irrigation Authorities so as to determine the type of structure most suitable from this consideration. The report prefacing the estimate for such works should contain unambiguous information on this aspect.

(2) In cases where adequate and assured closure periods are not expected to be available, foundations requiring open excavation in the canal portions should be avoided even though that may be most suitable type from other technical considerations viz. scour depth and safe bearing capacity of subsoil. In such cases, either pile foundation or shallow/deep well foundations depending on the suitability of the subsoil strata should be adopted. Since such contingencies of non-availability of adequate closure periods would normally arise in the cases of major canals only, it should generally be possible in such situations to construct well foundations by constructing temporary islands without creating appreciable constriction of waterway of the canals.

(3) The selection of the type of substructure should also be made to suit the expected, assured closure periods and the normal supply level of the canals. In case, adequate canal closures for executing conventional type of substructure are not expected to be available, the foundation wells themselves may be continued up-to the normal supply level.

(4) The number of spans should be minimum consistent with economy so as to have minimum possible number of foundations located in the canal bed. In case of smaller canals, it may even be preferable to provide a single span so as to altogether avoid the problems, associated with the construction of foundations and piers in the canal bed.

(5) As the centering for superstructure would have to be supported on piles driven in running water, the type of superstructure should be selected from considerations of availability of centering and shuttering equipment. In some cases, it may be preferable to adopt superstructures which can be laid without any centering or alternatively suspended centering should be used.

APPENDIX - 8
(Cl.2.2.14.2)

PROCEDURE FOR PREPARATION OF DETAILED ESTIMATES FOR ROAD OVER/UNDER BRIDGES TO BE CONSTRUCTED ON NATIONAL HIGHWAYS AND ACCORD OF TECHNICAL APPROVAL

1. Based on the General Arrangement Drawings to be approved by M/o RT&H (and subject to modifications or suggestions, if any, made by them in regard to the general requirements of siting, alignment, horizontal or vertical profile, final road levels, roadway, footpaths, design loadings and material specifications etc.), the Railways will prepare abstract estimates, designs and drawings and accord technical approval for the road over bridges proper.

2. Then the Railways, need to send only abstract estimates (with quantities and cost for different items) to M/o RT&H through the respective State Public Works Department. M/o RT&H will have a broad scrutiny of the abstract estimate and accord financial sanction for their share of cost. If there are any glaring discrepancies in quantities etc., the same will be pointed out to the railways for necessary correction. Thereafter, the railway authority will issue financial sanction to meet their share of cost.

3. In any particular case involving RCC or pre-stressed concrete designs, the Railways, if they so desire, may send the detailed design and drawings also for the views or comments of M/o RT&H and the same may be got incorporated suitably, in their designs and estimates, before the Railways accord final technical approval to the scheme and before forwarding abstract estimates to the M/o RT&H.

APPENDIX – 9

[Cl.3.2 (vi)]

GENERAL ABSTRACT OF COST

Sl.No.	Items of work	Amount
1.	Bridge Proper	
2.	Protective works	
3.	Approaches	
4.	Miscellaneous Items	
	Total: A	
	Add for contingencies at 3 per cent of A B	
	Total: A+B	
	Add 1 per cent for quality control on selected items needing control to be exercised at site C	
	Add for work charged establishment on A+B @ 2 per cent for works costing upto Rs. 25 lakhs	
	@ 1.5 per cent for works costing above Rs. 25 lakhs & upto Rs. 50 lakhs @ 1.0 per cent for works costing above Rs. 50 lakhs D	
	Add 9 per cent for agency charges for National Highway works on A+B E	
	Total:A+B+C+D+E=F	
	Total cost of work:'F' (suitably rounded Of)	

APPENDIX - 10
(Clause 4.2.2.4)

TIME SCHEDULE FOR BIDDING ACTIVITY AS PER STANDARD BIDDING DOCUMENT

Procedure for award of civil work contract to be effective from 04.07.2000 (LCB)

S. No.	Steps	Information to be included, documents to be examined and other details	Time Frame (Time reckoned from receipt of bid) for completion of step
1.	Invitation of applications for pre-qualification of contractors	(As per existing procedure)	
2.	Sale of PQ Document	(-do-)	
3.	Receipt of PQ applications	(-do-)	
4.	Evaluation of PQ applications	(-do-)	
5.	Clarification from applicants	(-do-)	
6.	Intimation of PQ results	The estimated cost(s) to be awarded shall be within pre-qualification limit of the contractor. Current Bid Capacity should be more than the estimated cost of the package	
7.	Finalisation of bid document	Changes in 'Instructions to Bidder' to be incorporated, to be in conformity with suggested changes.	
8.	Invitation of bids	(As per existing procedure)	
9.	Sale of bid documents	(-do-)	
10.	Bid Evaluation Committee	(-do-)	

11.	Receipt of Bids	To be received up to the date and time specified. Bids received late not to be accepted and to be returned unopened. Bids shall be sealed (original + copy) at the time of receipt. Bid security and technical bid including equipment, personnel, programme, etc., each in separate sealed envelope and both inside another sealed envelope. Financial bid containing original bill of quantities (BOQ) and copy of BOQ, to be furnished in another sealed envelope. All to be put in an outer sealed envelope.	Day 0
12.	Opening of Bids	- Opening of envelope containing 'bid-security and technical bid' - Check form, amount validity period and bank of bid security. If it does not conform to the Bid Document, the envelopes containing remaining 'technical bid' and 'financial bid' to be returned upopened. The sealed envelope containing financial bid to be signed by the bid opening committee members and representatives of bidders. - Opening of envelope containing 'Original BOQ' of only those bidders whose technical bid is qualified.	Day 0
13.	Evaluation of Technical Bids	Evaluation of Technical Bids by the Evaluation Committee - Write to Banks for confirmation of Bid Security to get response within 7 days. - Check eligibility. The estimated cost of the package to be awarded is within the pre-qualification limit or the balance of pre-qualification limit.	Day 1

		- Checking of updation of pre-qualification information: (a) Debarring, expulsion and termination of contracts - Any such affirmative information will disqualify. (b) Identity and composition of firm - no change from pre-qualification to be permitted. (c) Information for current bid capability - Check that the current bid capacity is higher than the estimated cost. - Checking of the bids - Checking of Power of Attorney submitted - Checking of confirmation of bid security from issuing bank - Affidavit furnished - JV Agreement (if any) submitted - Availability of Credit Line - Work Programme - Key personnel - Key equipment - Prepare list of queries to be asked from bidders, and issue of letter to the bidders i/c intimation of date of opening of financial bid on Day 21 - Bidders response to the letter seeking clarification - Meeting of evaluation committee to examine submitted response and finalise list of responsive bidders.	Day 7 Day 10 Day 17 Day 20
14.	Opening of envelope containing Financial Bids	Opening of financial bid in the presence of the bidders' representatives. - Announcing of total bid amount and rebate/addition - Checking of number of corrections on each page.	Day 21

		- Each page of BOQ and rebate/addition to be initiated by the member of evaluation committee - Number and corrections on each page to be indicated and initiated by the members of evaluation committee - Checking of arithmetical calculations of BOQ and announcing the same - Bid opening report	Day 21
15.	Evaluation Committee for evaluation of financial bids and Evaluation Report	Meeting of Evaluatoin Committee to consider the bid prices of bidders and to recommend the award of work	Day 24
16.	Approval of the competent authority	Submission of the evaluation report to the competent authority and approval of evaluation	Day 35
17.	Award of Work	Issue of award letter	Day 40

APPENDIX - 11
(Cl. 6.3.10)

IMPORTANT POINTS PERTAINING TO REVISED ESTIMATES FOR NH BRIDGE WORKS

1. **Estimate report:**

- Need for revision and detailed reasons for change in scope, specification and rates, etc.
- detailed note on each of the items where huge excess has occurred as compared to the sanctioned estimate.
- Drawing reference to the Ministry's letters approving changes in scope, in dimensions, in specifications, etc. and approving tenders.
- Present stage of work (in progress or already completed), alongwith date of award of work, date of commencement of work and date of completion of the work.
- If the work has already been completed, explain why the revised estimate was not submitted in time.
- If completed, completion drawing for the work may also be furnished.
- For provisions of restoration of damages by rains, floods, etc. quote the letter sent to the Ministry indicating the damages and their occurrences. Give reasons why the restoration of the damages should not be the responsibility of the contractor?

2. **Certificates required:**

- Certificate for cent per cent arithmetical check by a responsible officer,
- the land acquisition rates have been ascertained from the competent land acquisition authority,
- That the estimate does not provide for the cost of land belonging to the State Government and that this land will be available free of cost for the National Highway bridges and appurtenant works,
- That the compensation rates for land acquisition do not include agency charges,

- That the estimate is based on actuals in the case of completed items/works.

3. **Compliance with technical and inspection notes:**

- Reports of compliance with technical and inspection notes issued by the Ministry.

4. **Comparative Statement:**

- Comparative statement
- detailed reasons for excess/savings.

5. **Abstract of cost:**

- provision for all needed items.
- provision for dismantling of diversion bridge after completion of the new bridge.
- Do not provide any major lump-sum provision. If required to be provided, these should be supported by detailed sub estimates with proper justification for exceeding the sanctioned provisions if any or for including any new item not covered by the sanctioned estimate.
- Indicate as to which rates are based on actuals, on tender, on the current schedule and on the analysis,
- Give credit for the salvage value of dismantled materials of the existing structure, if any,
- Apportionment of cost wherever applicable between the concerned authority e.g. between road and rail authorities for over/under bridges in replacement of level crossings, between roads and irrigation authorities where bridge requires reconstruction because of coming up of irrigation project, between the Centre and State for bridges on bypasses passing through Municipal limits, where as per the existing policy on National Highway links, land for parallel service roads has to be acquired at the State cost along with the land for byepass and later on parallel service roads are to be provided by the State at their cost before urbanisation is authorized.

- Correct provision for centages. Centages in the case of completed works should be as per actuals limited to permissible limits

6. **Details of measurements:**

- details of measurements for all items figuring in the abstract of cost,
- separate measurements giving the details of the work found necessary consequent to heavy erosion by rains, floods, etc.

7. **Contract documents:**

- enclose a copy of the contract agreement in full (not piecemeal).
- in case of items where extra due to any clause in the contract like escalation clause is admissible, copies of necessary letters etc. justifying in detail the extra amount on this account may be furnished.

8. **Analysis of rates:**

- analysis of all the rates for the items which are neither covered by the tenders nor by the schedule of rates.
- analysis for supplementary tender rates have also to be furnished.
- Quarry or borrow area charts in support of the leads adopted in the rate analysis may be furnished,
- Full details regarding the extra amount spent for steel/ cement, etc. including source and quality of materials, rate of procurement and the need for paying higher rates,
- Reasons and supporting data for changes in quarries of stone aggregate and borrow area.

9. **Designs:**

- drawing reference to Ministry's letter approving the design for the bridge/guidebund, etc.
- drawing reference to MOST letter regarding approval of

changes, if any, in design from those provided in the sanctioned estimate (like changes in span arrangement, change in linear waterway, type and depth of foundation, etc.)

- remarks in respect of design assumptions made in the sanctioned estimate having been realized at site.
- Quoting State PWD letter seeking Ministry's approval wherever specified in the technical note accompanying the sanction letters.

10. **Drawings:**

- enclose all the drawings viz. Index map, site plan, general arrangement drawing of the bridge/guidebund with supporting drawings.
- draw reference to any standard drawing being used alongwith justification for departure, if any.
- The drawings should clearly show both the original and revised proposals in case there are any differences.
- Indicate whether approval of the Ministry was sought wherever suggested in the technical note.

11. **Audit paras:**

- brief report on pending audit paras.

12. **Pending claims:**

- brief report on claims pending settlement.

13. **Departmental execution:**

- if any or all the items of the work have been executed departmentally at rates different from the sanctioned estimate, the rate analysis of all such items may be furnished.

14. National Highways (Bridge works)

Statement showing excess/savings and deviations in cost and quantities as compared with the original estimate in respect of construction of bridge in km————————nh no.———————— job no————————————————

(Amount in rupees)

S. No.	Items of Works	Original sanction Estimate			Revised estimate			Savings/excess due to variation in quantity			
		Qty	Rate	Amt.	Qty	Rate	Amt	Qty Col 6-3	Rate same as	Saving (-)col. 9x10 Amt	Excess (+)col. 9x10 Amt.
1	2	3	4	5	6	7	8	9	10	11	12

Savings/Excess due to variation in rates.			Total savings/ Excess		Remarks and justification for deviations from the sanctioned estimate
Qty same as Co.6	Rate Col. (7-4) (-)or (+)	Savings (-)Cols. (13x14) Amt.	Excess (+)Cols (13x14) Amt.	Saving (-)Cols. (11x15) Amt.	Excess(+) Cols.(12x16) Amt.
13	14	15	16	17	18 19

(I) As provided in the original sanctioned estimate.

(II) New and/or deviated items (Note: The work done/to be done by different executing agencies should be shown separately)

(III) Excess due to difference in cost of procurement and supply of materials like.
(1) Cement
(2) Steel
(3) Other materials.

Total.

(IV) Centage charges
(a) Quality Control
(b) Contingencies
(c) W/c establishment
(d) Agency charges

Total

APPENDIX – 12
(Cl.7.2.2.3)
Form: QC-I
Date:
Job:

SCHEDULE OF CONCRETE MIXES: CONTRACT REQUIREMENTS

Grade of concrete	
Type of cement (OPC/PPC) I.S.No.	
Type of aggregate I.S. 383	Coarse
	Fine
Permissible standard deviation Kg/cm^2	
Minimum cement content kg/m^3	
Workability Slump (mm)	
Compacting factor	
Maximum free-water cement ratio	
Admixtures	Description:
	Quantity:

Additional information, if any:

Form QC-2
Date:

Job:

CONCRETE MIX DESIGN

(I) Contract requirements:

(1) Location of the pour : _____
(2) Characteristic strength : _____
(3) Standard deviation (SD)
(Ref. Form QC-1) : _____
(4) Margin = 1.65 x SD : _____
(5) Target mean strength = characteristic
strength + margin : _____
(6) Cement (a) Type OPC/PPC
(B) Make Indian/Imported
(7) Aggregate type (a) Coarse crushed/shingles
(b) Fine River sand/crushed
(8) Maximum aggregate size : _____
(9) Maximum free W/C ratio : _____
(10) Minimum cement content : _____ kg/m^3
(11) Maximum cement content : _____ kg/m^3
Ref Form No. QC-1

(II) Text data for materials:

(1) Cement (a) Setting time Initital _____ min.
Final _____ min.
(b) Compressive strength (kg/cm^2) 3 days 7 days
(a) As per manufacturers certificate _____ _____
(b) As per field test _____ _____

(2) Bulk density - Coarse aggregate _____ kg/m^3
- Fine aggregate _____ kg/m^3
(3) Specific gravity _____
- Coarse aggregate
- Fine aggregate _____

(4) Free (Surface moisture)

- Coarse aggregate _____%
- Fine aggregate _____%

(5) Sieve analysis

(A) Coarse aggregate - Graded 40 mm/20mm/12.5 mm

Per cent passing through I.S. sieve sizes

63mm	40mm	20mm	12.5mm	10mm	4.75mm

(B) Fine aggregate - Sand/Quarry dust Zone

Per cent passing through I.S. sieve sizes

10mm	4.75mm	2.36mm	1.18mm	600u	300u	150u

(III) DETAILS OF MIX:

(1) Free-water/cement ratio : _____
(2) Aggregate/cement ratio : _____
(3) Coarse/Fine aggregate ratio : _____
(4) Quantities required for concrete mix
cement : _____kg
Coarse aggregate : _____kg
Fine aggregate : _____kg
Water : _____lt

Note:

All aggregates should be prepared so as to be surface dry while used for trial mix.

FORM QC-3

AGGREGATE SIEVE ANALYSIS REPORT

Job: Date: ——————————

Coarse aggregate: Graded 40mm/20mm/12.5mm
Source of supply:——————Weight of sample: ——————kg

I.S. Sieve size	Weight retained (kg)	Cumulative weight retained (kg)	% Retaining	% passing as per IS-383			Remarks
				40mm	20mm	12.5mm	
63mm				100	-	-	
40mm				95-100	100	-	
20mm				30-70	95-100	100	
12.5mm				-	-	90-100	
10mm				10-35	25-55	40-85	
4.25mm				0-5	0-10	0-10	

Fine aggregate:
Source of supply—————— Weight of sample ——————kg

I.S. Sieve	Weight retained (gms)	Cumulative Retaining (gms)	% Retained	% Passing	% Passing For Zones				Remarks
					I	II	III	IV	
10mm					100	100	100	100	
7.5 mm					90-100	90-100	90-100	95-100	
2.36mm					60-95	75-100	85-100	95-100	
1.18mm					30-70	55-90	75-100	90-100	
600µ					15-34	35-59	60-79	80-100	
300µ					5-20	8-30	12-40	15-50	
150µ					0-10	0-10	0-10	0-15	

FORM QC-4

Job:———————————Date:———————————

Cube Test Results

Characteristic strength : ———kg/cm²
Target mean strength : ———kg/cm²
Aggregate /cement
Ratio : ———————
Water/cement
Ratio : ———————
Sand content : ———————
Workability
(a) Slump : ———————
(b) Compaction
factor : ———————

Works Test/Trial Mix

Date of casting : ———————
Location : ———————
Day's pour : ———m³
Size of specimen : ———————
Cement type : ———————
Actual cement
consumption : ——kg/m³
Tested on
(Machine) : ———————

Sl.No.	Identification	Age of Specimen (days)	Weight of Specimen (kg)	Compressive strength (kg/cm²)	Remarks

APPENDIX - 13
(Cl.7.5.2.1 xiv)

PROFORMA OF PROGRESS OF WELL STEINING AND SINKING

Note: Give the number plan of the wells on the first page.

1	2	3	4	5
6	7	8	—	—

Heading of columns shall be as given below.

Column No.	Heading
(1)	Date
(2)	Time of observation
(3)	Well No.
(4)	Work done during 24 hours preceding time of observations steining/sinking
(5)	Steining works:
	(i) R.L. at the top of well and the time of observation.
	(ii) R.L. at top of well at the time of last observation
	(iii) Steining done since last observations (i) minus (ii)
	(iv) Gauge upto which steining done todate including height of curbs
	(v) R.L. of bottom of curb (i)-(iv)
	(vi) R.L. of L.W.L. as per contract.
(6)	Total sinking done up-to-date:
(7)	Total sinking done as per last observation
(8)	Sinking done since last observation (6)-(7)
(9)	Sump observation:
	(i) Depth of bottom of sump below top of well
	(ii) Magnitude of sump 9(i) – 5(iv)
(10)	Strata met with at the time of observation
(11)	Any obstacle met since last observation
(12)	Any plastering done since last observation
(13)	Any sand blowing took place since last observation.

(14) Kentledge observations:
- (i) Extra kentledge over the well
- (ii) Eccentricity along X - axis
- (iii) Eccentricity along Y - axis
- (iv) Approximate total quantity of dredged materials on last observation
- (v) Approximate quantity of dredged materials at the time of observation
- (vi) Approximate quantity of dredged materials since last observation

(15) Is any special method of sinking being employed at the time of observation?
If so, give brief description in Remarks column

(16) Remarks.

(17) Signature of official taking the observation

(18) Signature of Assistant Engineer in token of check.

(19) Signature of Executive Engineer/Superintending Engineer in token of having seen the register.

APPENDIX - 14
(Cl.7.5.2.1)

PROFORMA FOR RECORDING TILTS AND SHIFTS OF WELLS

Note: Give the numbering plan of the wells on the first page.

1	2	3	4	5	——
	*				

*Heading of columns shall be as given below:

Column No. | Heading

(1) Date
(2) Time of observation
(3) Well No.
(4) Total steining done in the well up-to-date (vide column 5(iv) of proforma of progress of sinking)
(5) Total sinking done up-to-date (vide column 6 of proforma of progress of sinking).
(6) Reduced levels at the gauge marks on the tilted plane:
  (i) Along X axis (traffic axis)
  ——————Side——————
  (say north side) (say south side)
  (ii) Along Y axis (perpendicular to traffic axis)
  On downstream side On upstream side
(7) Difference in levels taken on the tilted plane:
  (i) Along X-axis.
  (ii) Along Y-axis

(8) Extent of tilt:
  (i) Along X-axis
  (ii) Along Y-axis

(9) Shifts:
  (i) Along X-axis
  (ii) Along Y- axis

(10) Action being taken in case tilt has exceeded 1/80 and shift 150 mm
(11) Remarks.
(12) Signature of the official taking observation
(13) Signature of Assistant Engineer in token of check
(14) Signature of Executive Engineer/Superintending Engineer in token of having seen the register

APPENDIX - 15
(Cl.7.5.2.1)

STATEMENT SHOWING PARTICULARS OF DIFFERENT METHODS ADOPTED AND PHENOMENON ENCOUNTERED DURING WELL SINKING ON DIFFERENT WELLS

of ..... bridge on ..... Road ..... District .....
1. Well No ..... (Below ..... Side Abutment/Pier No.....

1	2	3	4	5	6
*					

*Heading of column shall be as given below:

Column No.	Heading
1.	Date
2.	Total steining uptodate
3.	Total sinking uptodate
4.	Working progress on steining or sinking
5.	*Total weight available for sinking:* (i) Weight of well for portion below water level allowing for buoyancy (ii) Weight of well above water level (iii) Kentledge weight
6.	Total
7.	*Eccentricity of kentledge:* (i) Along X-axis (ii) Along Y-axis
8.	Hours of working for which sinking was done
9.	*Quantity of Material taken out from well Pocket:* (i) During last 24 hours (ii) Per running metre of sinking of well done in 24 hours
10.	Details of explosive if used and name of person in whose presence it was used.

11. Whether dewatering was done during sinking and if so how much below river water level
12. Whether dewatering was done after bottom plugging and if so how much below river water level
13. Rate of rise of water inside the well in dewatering test
14. Remarks
15. Signature of person recording the information

USEFUL TABLES

Table 1. Conversion Table

(1) Length

Inches x 2.54 = cm	cm x 0.3937 = Inches
Feet x 0.3048 = m	m x 3.2808 = Feet
Miles x 1.6093 = km	km x 0.6214 = Miles

(2) Area

Sq. Inches x 6.4516 = cm^2	cm^2 x 0.155 = Sq. in.
Sq. feet x 0.0929 = m^2	m^2 x 10.7636 = Sq.ft.

(3) Volume

Cubic inch x 16.39 = cm^3	cm^3 x 0.061 = cubic inch
Cubie feet x 0.0283 = m^3	m^3 x 35.287 = cubic feet
Gallons (Imp.) x 4.546 = Lit	Litres x 0.22 = Cubic feet

(4) Weight

Pounds x 0.4536 = kg	kg x 2.205 = pounds
Ton x 0.984 = tonne (2240 lb)	tonne x 1.0158 = ton (1000 kg)
Kilogram x 9.81 = Newton force	Newton x 0.102 = kilogram force

(5) General

Lbs/sq.inch x 0.0703 = kg/cm^2	kg/cm^2 x 14.223 = lb/sq.in.
Newton / m^2 x 1.00 = Pascal	Pascals x 1 = /Newton/m^2
1 Mpa x 10.2 = kg/cm^2	kg/cm^2 x 0.098 = Mpa
Newton / mm^2 x 10.2 = kg/cm^2	kg/cm^2 x 9.81 = Newton/mm^2

Table 2. Density of Materials

	Materials	Weight in tonnes per cu.m.
(1)	Ashlar (granite)	2.7
(2)	Ashlar (Sand stone)	2.4
(3)	Brick work (pressed) in cement mortar	2.2
(4)	Brick work (common) in cement mortar	1.9
(5)	Asphalt concrete	2.2
(6)	Macadam (binder premix)	2.2
(7)	Macadam (rolled)	2.6
(8)	Plain cement concrete.	2.2
(9)	Plain cement concrete with plums	2.3
(10)	Reinforced cement concrete	2.4
(11)	Prestressed cement concrete	2.5
(12)	Compacted earth	1.8
(13)	Gravel	1.8
(14)	Loose sand	1.4
(15)	Wet compressed sand	1.9
(16)	Coursed rubble masonry in cement mortar	2.6
(17)	Wood	0.8
(18)	Cast iron	7.2
(19)	Steel (rolled or cast)	7.8
(20)	Water	1.0

Table 3. Area of Steel Bars

Bar dia (mm)	Area (in cm^2)	Area of steel provided in cm^2 for different spacing				
		100mm	125mm	150mm	200mm	250mm
6	0.283	2.83	2.26	1.89	1.41	1.13
8	0.503	5.03	4.02	3.35	2.51	2.01
10	0.786	7.86	6.28	5.24	3.93	3.14
12	1.131	11.31	9.05	7.54	5.65	4.52
16	2.011	20.11	16.08	13.41	10.05	8.04
20	3.143	31.43	25.14	20.94	15.71	12.57
22	3.803	38.03	30.41	25.34	19.01	15.21
25	4.911	49.11	39.27	32.72	24.54	19.63
28	6.160	61.60	49.36	41.05	30.79	24.63
32	8.046	80.46	64.34	53.61	40.21	32.17
36	10.183	101.83	81.43	67.86	50.90	40.72
40	12.571	125.71	100.53	83.77	62.83	50.26

Table 4. Dimensions of rolled steel equal angles

Designation	Size A x B mm mm	Thickness t mm	Sectional Area a Cm^2	Weight per Metre w Kg^2
ISA 7575	75x75	5.0	7.27	5.7
		6.0	8.66	6.8
		8.0	11.38	8.9
		10.0	14.02	11.0
ISA 9090	90x90	6.0	10.47	8.2
		8.0	13.79	10.8
		10.0	17.03	13.4
		12.0	20.19	15.8
ISA 100100	100x100	6.0	11.67	9.2
		8.0	15.39	12.1
		10.0	19.03	14.9
		12.0	22.59	17.7
ISA 130130	130 x130	8.0	20.22	15.9
		10.0	25.06	19.7
		12.0	29.82	23.4
		15.0	36.81	28.9
ISA 150150	150x150	10.0	29.03	22.8
		12.0	34.59	27.2
		15.0	42.78	33.6
		18.0	50.79	39.9
ISA 200200	200x200	12.0	46.61	36.6
		15.0	57.80	45.4
		18.0	68.81	54.0
		25.0	93.80	73.6

Table 5. Dimensions of Steel Plates

Thickness t mm	8	10	12	14	16	18	20	22	25
Width b mm	**Area in sq. cm.**								
100	8.00	10.00	12.00	14.00	16.00	18.00	20.00	22.00	25.00
125	10.00	12.50	15.00	17.50	20.00	22.50	25.00	27.50	31.25
160	12.80	16.00	19.20	22.40	25.60	28.80	32.00	35.20	40.00
200	16.00	20.00	24.00	28.00	32.00	36.00	40.00	44.00	50.00
250	20.00	25.00	30.00	35.00	40.00	45.00	50.00	55.00	62.50
	Weight in kg. per metre								
100	6.3	7.8	9.4	11.0	12.6	14.0	15.7	17.5	19.6
125	7.8	9.8	11.8	13.7	15.7	17.7	19.6	21.6	24.5
160	10.0	12.6	15.1	17.6	20.1	22.6	25.1	27.6	31.4
200	12.6	15.7	18.8	22.0	25.1	28.3	31.4	34.5	39.2
250	15.7	19.6	23.6	27.5	31.4	35.3	39.2	43.2	49.1

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REFERENCES

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